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Author(s): Orcun Kurum

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**Effects of 2 Days Sodium Bicarbonate Loading on  
Simulated Football Performance Test.**

by

Orcun Kurum

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## Abstract

### The Effects of 2 Days Sodium Bicarbonate Loading on Simulated Football Performance Test

Orcun Kurum

**Introduction** - There is well-documented researches exist on sodium bicarbonate, however, not many studies have examined the effectiveness of this ergogenic aids during prolonged exercises also including a sport specific performance test. The primary purpose of this study was to determine whether a short-term (2 days) supplementation of sodium bicarbonate ( $\text{NaHCO}_3$ ) enhances repeated sprint performance and time to exhaustion in a simulated football performance test (Loughborough Intermittent Sprint Test) which lasts for 90 minutes.

**Methods** - Seven healthy males (Mean age =  $24 \pm 1.6$  years and predicted mean  $\dot{V}\text{O}_{2\text{max}} = 49.4 \text{ ml kg}^{-1} \text{ min}^{-1}$ ) participated in this experimental study using a double-blind, randomized, crossover study design was used. All subjects completed three conditions, except the control condition, the others included test drinks followed by a 5-day washout period between these two conditions: 1) control (no drinks), 2) placebo/drug (Pl;  $\text{NaCl}$ ;  $0.045 \text{ g kg}^{-1}$ , Sb;  $0.5 \text{ g/kg bw NaHCO}_3$ ), and 3) same as 2<sup>nd</sup> condition. During each condition, sprint times, exhaustion times and rating perceived exertion (RPE) were assessed. In addition to this, before the test day, gastro intestinal (GI) distress questionnaires were used to assess the number and severity of symptoms during the supplementation period.

**Results** - The main findings were; 1) Sodium bicarbonate loading produced slightly (3.2%) but significantly greater ( $p = .000$ ) sprint performance than the placebo in some periods of the exercise session (LIST) and 2) Two days of Sb supplementation was sufficient to increase repeated sprint performance compared to the placebo trial. However, in contrast to

hypotheses, no benefits from supplementation were observed for time to exhaustion and perception of fatigue (RPE).

**Conclusion** – Considering that this current study found benefits from sodium bicarbonate loading during the 90 minutes simulated football performance test, it suggests that 2 days of sodium bicarbonate supplementation may improve repeated sprint performance. Future research on a greater sample size, a specific athletic population (professionals), and various exercise modes including ball activities would be beneficial in determining if this supplementation is worthwhile.

This paper is original and has not been submitted previously in support of a degree qualification or other course.

Date \_\_\_\_\_

Signature \_\_\_\_\_

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## **Chapter 1**

### **Introduction**

#### *Statement of the Problem*

Today's athletes are enjoying all time popularity in the history of sport. A hundred years ago while a couple of athletes were popular in some sports, nowadays they are more likely to be popular all over the world and they earn much more than the former professionals. Even the taking part in sports has reached the highest level in all time in high schools, in both amateur and professional athletics, (McArdle, Katch & Katch, 2009). This obvious increase in the number of athletics brings a more competitive environment to the sports and this is where the need for competitive advantages becomes crucial to improve performance. It is possible to improve performance in different ways, such as changing the amount of energy or carbohydrate intake, changing the environment of training (e.g., high altitudes) and of course using ergogenic aids. Although these strategies are useful, using ergogenic aids is by far the most common method to enhance the athletes' performance. Petroczi and Naughton, (2007) state that worldwide ergogenic aids (also referred to as dietary supplements) were used by around roughly 60% of athletes in 2007, and it will likely increase over the years.

Among the other dietary supplements, sodium bicarbonate ( $\text{NaHCO}_3$ ) is one of the most favoured ergogenic aids, which is also known as a buffer. The use of this substance is officially recognised by the World Anti-Doping Agency code (McNaughton, 2010). Sodium bicarbonate is also one of the most widely studied ergogenic aids when compared with other substances. Numerous  $\text{NaHCO}_3$  investigations concluded that  $\text{NaHCO}_3$  loading is shown to abate the effect of fatigue while also increasing power output in high intensity exercise bouts such as sprinting (Bishop, Edge, Davis & Goodman, 2004; Bishop & Claudius, 2005; Douroudos et al., 2006; Van Montfoort, Van Dieren, Hopkins & Shearman, 2004). These findings are very

important because in a regular football match, about 10% of the distance that players cover comprises sprinting (Reilly, 2005).

Since the 1980s the effects of bicarbonate ingestion on sports performance have been investigated (Burke & Pyne, 2007), but more interestingly the effect of acid-base balance in exercise was investigated more than 70 years ago (McNaughton, Siegler & Midgley, 2008). The reason why athletes use  $\text{NaHCO}_3$  is because it helps to delay the fatigue in endurance events due to the changes in acid-base balance (McNaughton, 2010).

Even though many athletes use ergogenic aids, not every study found improvements on performance. The main reasons for using the ergogenic aids are to reduce fatigue and increase power output. A study conducted by McNaughton, Siegler and Midgley (2008, p. 230) stated that "...decline in muscle adenosine triphosphate (ATP) or impaired electrochemical events of muscle contraction/relaxation production" are the potential reasons causing fatigue in terms of muscle energy production in high intensity exercises. When increasing the intensity of exercise, the accumulation of metabolites during exercise, such as hydrogen ions, causes an increase in lactic acid in the blood and this could be another explanation of fatigue and also the decrease in performance (McNaughton et al., 2008).

Many researches have shown that sprint performance can be improved by ingestion of sodium bicarbonate in terms of power output, total anaerobic work and delaying fatigue (Bishop et al., 2004; Bishop & Claudius, 2005; McNaughton, Backx, Palmer, Strange, 1999; McNaughton, Dalton & Palmer, 1999). It is possible to give some particular studies such as Lavender and Bird (1989), Bishop et al. (2004) and Bishop and Claudius (2005) in which they found that  $\text{NaHCO}_3$  supplementation enhanced power output levels in repeated sprints. Depending on

these studies, after ingesting the sodium bicarbonate supplementation, it is believed that improved buffering capacity of hydrogen ions causes the improvements in performance. During the intensive exercises, accumulation of hydrogen ions, mainly because of increases in lactic acid within the muscle, lowers muscle pH (McNaughton, 2010). It is thought that this fall in pH generates some changes in the body such as inhibiting muscular contraction in different ways. For instance, a low pH level limit the rate of resynthesis of ATP by inhibiting glycolytic enzymes also inhibits the release of calcium ions needed for muscular contraction and weakens the interaction between actin and myosin in the muscle cell (Lavender & Bird, 1989; Requena, Zabala, Padial & Feriche, 2005).

The main effect of bicarbonate supplementation on the body is stimulating extracellular buffering mechanisms where bicarbonate is known as one the most important buffering agent substances. With a number of mechanisms, bicarbonate is able to get rid of the accumulated hydrogen ion ( $H^+$ ) from the muscle cell. This maintains high intensity exercise through reducing the inhibition of muscular contraction. Body fluids already include  $NaHCO_3$  but taking it exogenously before exercise may improve performance (McNaughton, Backx, Palmer & Strange, 1999).

Normally, resting human arterial blood pH is approximately 7.4, which is slightly alkalotic, but post exercise blood pH may fall to, 7.1. At the same time, muscle pH reduces to 6.8 but using bicarbonate as a buffer helps to maintain the blood pH in optimal ranges, 7.35-7.45 (McNaughton, 2010). Several studies have shown that ingesting sodium bicarbonate raises bicarbonate concentrations and blood pH levels (McNaughton, Backx, Palmer & Strange, 1999; Douroudos et al., 2006; Requena, 2005; Van Montfoort, Van Dieren, Hopkins & Shearman, 2004). According to these studies, increased extracellular buffering agents, via

bicarbonate intake, help the body to lower the amount of metabolites such as hydrogen ions and lactate by sending them out of the muscle cell much quicker and it is thought that this is the main reason for improvements on sprint performance (Bishop & Claudius, 2005).

Also a study conducted by Van Montfoort et al. (2004) concludes that bicarbonate is possibly more beneficial to sprint performance than sodium lactate or sodium citrate. It is recommended by researchers to ingest sodium bicarbonate to enhance sprint performance (Bishop et al., 2004; Bishop & Claudius, 2005; Van Montfoort et al., 2004). Also bicarbonate was studied for long duration events and investigators found some benefit, which is that sodium bicarbonate supplementation can help to improve performance even in long lasting events ( $\geq 1$  hr), (McNaughton, Dalton & Palmer, 1999; Bishop & Claudius, 2005; Wu, Shih, Yang, Huang & Chang, 2010).

### *Statement of Purpose*

The primary purpose of this study was to determine whether a short-term (2 days) supplementation of sodium bicarbonate ( $\text{NaHCO}_3$ ) enhances repeated sprint performance and time to exhaustion in a simulated football exercise session (Loughborough Intermittent Sprint Test).

### *Research Hypotheses*

It was hypothesized that:

1. Supplementation of sodium bicarbonate will significantly increase the time to exhaustion between each LIST compared to placebo and control group.
2. Supplementation of sodium bicarbonate will significantly improve sprint times between mean sprint times of each period of LIST compared to placebo and control group.
3. Supplementation of sodium bicarbonate will significantly lower perceived feelings of fatigue compared to placebo and control group.

### *Significance of Study*

This is the first study to investigate whether a supplementation of sodium bicarbonate will enhance performance of the football players by using a simulated football performance test (LIST). This study will give further insight to the effects of this supplement on team sports and long duration events. Many coaches advise the use of sodium bicarbonate to maximize the training and performance of athletes. This supplement is also very accessible and can be found easily in any supermarket for under a pound. The results from this study can give insight to coaches as well as athletes, into which supplementation treatment will be the most effective in sports that involve repeated sprints.



### *Definition of Terms*

The following terms and abbreviations are defined as used in the study.

ATP (Adenosine triphosphate): A high-energy phosphate compound from which the body derives its energy.

Sb or NaHCO<sub>3</sub> (Sodium Bicarbonate): A chemical compound that is crystalline but often appears as a fine powder. Supplementing on sodium bicarbonate is theorized to aid in the acid-base balance system by buffering hydrogen ions.

RPE (Rating Perceived Exertion Scale): Also known as Borg 6 – 20, the original scale as developed by G. Borg, with the ratings between 6 to 20, which can correspond to 1/10 of the exercise heart rate.

LIST (Loughborough Intermittent Sprint Test): A running test that includes jogging, running and sprinting, designed to simulate the physiological demands of soccer matches which last for 90 minutes.

VAS (Visual Analogue Scale): A Visual Analogue Scale (VAS) is a measurement instrument that tries to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured. The subject marks on the line the point that they feel represents their perception of their current state.

## **Chapter 2**

### **Review of Literature**

#### *Introduction*

Sodium bicarbonate is a widely studied ergogenic aid in high intensity performance including not only running and cycling but also boxing and tennis. Through extremely high rates of energy turnover during high intensity exercise, muscle performance rapidly drops off (Hermansen, 1981). This decrease in performance can be explained via homeostatic changes within the muscle and the reduction of energy substrates (Hermansen, 1981).

There is well-documented researches exist on different ergogenic aids, however, not many studies have examined the effectiveness of these ergogenic aids during prolonged exercises. Most existing studies conducted their experiments under 60 minute duration and mostly using the running or cycling exercise modes. Studies that used a sport specific exercise and longer durations than 60 minutes are in a minority. In regards to Sb, there are only a few studies that tested the sodium bicarbonate supplementation on exercise performance, which lasts 60 minutes or more (Bishop & Claudius, 2005; Price, Moss & Rance, 2003).

The primary purpose of this study is to determine if a two-day supplementation of sodium bicarbonate will improve the performance during an exercise session that lasts for 90 minutes. This literature review will evaluate the current research of sodium bicarbonate's ergogenic effect along with their combination.

#### *Sodium Bicarbonate Supplementation*

A number of investigations found that sodium bicarbonate (baking soda) can boost performance drastically by increasing the buffering power through increasing bicarbonate

stores (Bishop et al., 2004; Bishop & Claudius, 2005; Burke & Pyne, 2007; McNaughton, Dalton & Palmer, 1999b; Van Montfoort, 2004). Similar to the other ergogenic aids, sodium bicarbonate supplementation was mostly tested on highly demanding sports including different modes of exercises and the results of effectiveness to the performance are mostly positive (Douroudos II et al., 2006; Lavender & Bird, 1989).

In a study of McNaughton and Cedaro (1991), they examined sodium bicarbonate loading on rowing ergometer performance in elite rowers. The performance was determined by a maximal effort rowing test during 6 minutes. Results of the study showed that subjects who consumed the sodium bicarbonate drink rowed significantly greater distance than the placebo trial. The analysis of the blood measures also showed that supplementing on sodium bicarbonate significantly increased blood pH and bicarbonate ( $\text{HCO}_3$ ) levels of the participants. The researchers concluded that it was the rise in bicarbonate ions in the blood that may have made it easier to remove a greater number of hydrogen ions from the muscle cell (McNaughton & Cedaro, 1991). The following study of McNaughton (1992) found that sodium bicarbonate supplementation improved 60-second cycle performance. Similar to his previous study, it was also found that resting pH levels were significantly higher in the bicarbonate-supplemented group compared to the placebo group.

Research undertaken by Lindh, Peyrebrune, Ingham, Bailey and Folland (2008) also found advantageous benefits of sodium bicarbonate supplementation on swimming performance.

The researchers tested participants on 200 metres distance and they found the mean swimming performance under Sb conditions was significantly faster than the placebo ( $p < 0.05$ ). In addition to this, blood pH and bicarbonate concentrations were also significantly ( $p < 0.05$ ) elevated before the exercise test. Like most studies, Siegler et al. (2007) also found

similar blood pH and bicarbonate increases while supplementing on sodium bicarbonate during cycling at maximal effort. Another study conducted by Douroudos II et al. (2006) also investigated the effects of sodium bicarbonate ingestion on a maximal effort performance. The researchers stated that subjects who ingested sodium bicarbonate significantly increased mean power output while the placebo condition was found to be ineffective on performance. The improvement in overall power output was attributed to sodium bicarbonate's ability to make a more alkaline pH by increasing blood bicarbonate levels (Douroudos et al., 2006). These investigations justify the idea that ingestion of sodium bicarbonate may enhance our acid-base balance system and therefore improve high-intensity performance.

McNaughton, Siegler and Midgley (2008) did a very extensive review and the researchers suggest that during repeated intermittent sprint bouts it is more possible to reach a conclusive research on sodium bicarbonate's ergogenic potential. Early research by Costill, Verstappen, Kuipers, Janssen and Fink (1984) investigated the effects of sodium bicarbonate on multiple bouts of cycling performance (5 x 1 min bouts, 100%  $\dot{V}O_{2max}$ ). As a result, cycling performance times were significantly lower ( $p = 0.01$ ) in subjects that supplemented on Sb during the last bout of exercise. The researchers also showed that resting blood pH increased on average from 7.34 to 7.41 and in the same time bicarbonate levels rose from 27.5 to 31.0 mm in the sodium bicarbonate group. These levels were all significantly higher than the placebo group. Costill et al. (1984) was one of the first studies that showed sodium bicarbonate supplementation, or in other words, increasing the blood pH and bicarbonate levels, can significantly enhance performance.

Correspondingly, research conducted by Bishop et al. (2004) found that it is possible to significantly improve the power output and total work after ingestion of sodium bicarbonate

in repeated sprint sessions. Furthermore, the researchers used recreational sport participants to complete a series of five short (6-second) sprints with a recovery of 30 seconds. Blood analyses were similar to previous studies, lower blood concentrations of hydrogen ions ( $H^+$ ) and higher bicarbonate levels after sodium bicarbonate supplementing was noted (Bishop et al., 2004). Although there was no difference reported in total work or percent fatigue, improvements found in sprints three through five occurred. This increase in performance in sprint 3-5 may be explained by the higher levels of bicarbonate allowing for removal of hydrogen ions during the 30-second rest period (Bishop et al., 2004).

As mentioned before, Lavender and Bird (1989) also examined sodium bicarbonate supplementation on repeated sprints and the method they used in that study was a repeated and modified 10-second Wingate protocol. As expected, they found that the bicarbonate trials showed significantly greater mean power output when compared to the placebo trials during the most (8 out of 10) repeated ten-second cycle sprints.

Supplementation of sodium bicarbonate has also been shown to significantly increase time to exhaustion in some studies; to give an example the research undertaken by Van Montfoort et al. (2004). Researchers compared supplementation of four buffering agents: bicarbonate, citrate, chloride and lactate. They concluded that sodium bicarbonate proved to be most effective in increasing time to exhaustion and reducing fatigue. This study, combined with previous research on benefits in power output, suggests that sodium bicarbonate may enhance sprint performance factors such as power output and fatigue. Several investigators also have reported a decrease in rating of perceived exertion or an increase in performance during high-intensity exercise after bicarbonate administration (Maughan & Burke, 2002). Example to another encouraging research; in a study conducted by McNaughton (2010) a  $NaHCO_3$  dose

of 0.3 g/kg body weight was used in a randomised controlled trial on 10 well-trained male cyclists undertaking 1 h maximal effort cycle ergometry. The cyclists performed, on average, 13% and 14% greater total work with NaHCO<sub>3</sub> than the control and placebo groups respectively.

However, the effects of Sb on performance are not always positive, although many studies have shown that sodium bicarbonate ingestion modifies the blood acid-base balance (Horswill, 1988). A study by Horswill (1988) was not able to find improvements in 2-minute sprint bouts but it may be that the reason was too low doses (0.10-0.15-0.20 g kg<sup>-1</sup> body mass). Similarly to the previous study, peak power was tested during Wingate assessments but without any improvements observed again this may be due to the small dose of Sb, only 13g Sb per person (Inbar, Rotstein, Jacobs, Kaiser, Dlin & Dotan, 1983). In respect of repeated sprint bouts, most researches conducted until this time shown the initial sprint of multiple sprint trials shows no significant improvement (Bishop et al., 2004; Lavender & Bird, 1989). The reason of not having improvement in single short sprints may be a single sprint is too short to commence extracellular buffering mechanisms. On the other hand, the repetitive nature of multiple sprints may promote greater buffering power over time (Requena, 2005). Once buffering capacity get higher the athletes may take advantage of sodium bicarbonate supplementation such as peak power, fatigue and feelings of fatigue during later sprints sprint performance measures (Barber, 2010).

### *Sodium Bicarbonate: Dosing Regimens*

Present research suggests that sodium bicarbonate improves performance in different kinds of exercises but understanding the dosing regimens is very important since there are various methods of supplementing with sodium bicarbonate. In general, there are two popular

modes of administering sodium bicarbonate ingestion; these are acute and chronic supplementation. Most research conducted has used the acute method which involves a one time loading dose of 0.3 g/kg approximately 60-90 minutes prior to exercise which is also a time friendly method for both researcher and participant (Bishop, 2004; Douroudos II et al., 2006; Lavender & Bird, 1989; McNaughton & Thompson, 2001; Van Montfoort et al., 2004). For an 80 kg male athlete this dose is equal to 24 grams of sodium bicarbonate intake (Burke & Pyne, 2007). This has been considered the “traditional” method of sodium bicarbonate loading and is the least amount to see enhancement on performance. This acute method is also often shown to produce gastrointestinal side effects, such as nausea, vomiting and stomach cramping during exercise (McNaughton & Thompson, 2001, Van Montfoort et al., 2004).

The chronic method involves loading a larger dose of 0.5 g/kg of bicarbonate over several days (Burke & Pyne, 2007). Investigations showed that the chronic loading method, for many athletic competitions, may provide more of a benefit than an acute, one time, loading dose.

This idea forms the basis of a study by McNaughton (1999a), but not fully understood; as a result of changes in pH values and the body's bicarbonate levels during the chronic loading period, body can store the extra bicarbonate provided over a period of 5-6 days and able to use the extra buffer for enhancing exercise performance. This method of intake has also more advantage such as reducing the gastrointestinal side effects almost completely.

Effects of acute, as against chronic, ingestion methods of sodium bicarbonate were investigated in a study conducted by McNaughton and Thompson (2001) on anaerobic work and power output. In this study, subjects divided into an acute supplementation or chronic supplementation group in a randomized nature. The acute loading group ingested 0.3 g/kg 90 minutes before exercise the exercise test, on the other side, the chronic group, ingested 0.5

g/kg/day for 6 days and nothing on test day. Succeeding (2.) performance test and blood analysis was also carried out 2 days after the supplementation had finished. Analyses of this study conclude that the acute and chronic group showed similar performance benefits. Nevertheless, the chronic supplemented group considerably sustained improved performance two days after the supplementation ended. Blood pH and bicarbonate levels were also not changed after the first 24 hours of ingestion (McNaughton et al, 1999a). Additionally, the chronic supplementation group did not experience any gastrointestinal side effects, while the acute supplemented group did. The similar performance and blood measure results imply that chronic loading may be a more practicable and efficient way of ingestion than acute supplementation. Researchers concluded that since the positive benefits from chronic sodium bicarbonate supplementation lasted 2 days after supplementation ceased, a supplementation of less than 6 days may be just as effective and more feasible (McNaughton & Thompson (2001).

The similar performance and blood measure results suggest that chronic loading may be a more feasible and effective method of ingestion than acute supplementation. The authors concluded that since the positive benefits from chronic sodium bicarbonate supplementation lasted 2 days after supplementation ceased, a supplementation of less than 6 days may be just as effective and more feasible (McNaughton & Thompson, 2001).

In the study of Burke & Pyne (2007) they create a new approach besides the acute and chronic bicarbonate loading, named, 'serial loading'. A variation of the acute-loading regime is to load bicarbonate in small doses over consecutive days before a competitive event or race. The advantage of this method is that the muscle extracellular buffering capacity is enhanced with a reduced risk of gastrointestinal distress. Studies show that several days of split doses of bicarbonate build up blood buffer levels that persist for at least 24 hours after the last dose.



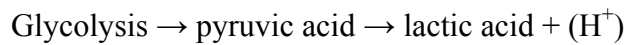
Therefore, this protocol could be used to achieve a loading preparation for multiple events over the same or successive days. Also it is believed that this approach would eliminate the need for any supplementation on race day. This kind of strategy would be welcomed by many athletes who would gladly avoid the distractions and possible adverse side effects (Burke & Pyne, 2007).

Also a study of Barber (2010) found clear positive effects of 2 days sodium bicarbonate loading on repeated sprint performance. The study included creatine loading and creatine combined with sodium bicarbonate loading, which was tested through 6 10-second repeated Wingate tests. Even the research conducted by Barber (2010) tested both creatine and Sb loading, the results of mean power values of sprints (for 3, 4, 5, & 6) showed that there was no significant difference between placebo and creatine conditions, but there were significant differences between placebo and creatine conditions with combined Sb ( $p < 0.0001$ ). Therefore, it was decided to use two days with split doses of Sb loading in this study because this protocol found enough to increase the blood bicarbonate levels (Barber, 2010) to improve the sprint performance without feeling any GI discomfort.

#### *Sodium Bicarbonate: Mechanism of Action*

As is known from many studies, sodium bicarbonate may aid in the acid-base balance system by buffering metabolites resulting from high intensity exercise. During high-intensity exercise, specifically after the utilization of PCr (phosphocreatine) has finished, energy needs are provided primarily by anaerobic glycolysis (Requena et al., 2005). During this energy system, the end product of glycolysis, pyruvic acid, is transformed to lactic acid, which

ultimately rebuilds glucose for energy (McArdle et al., 2009). In this process, lactic acid separates into a lactate molecule and a free hydrogen ion ( $H^+$ ).



Augmented  $H^+$  levels cause decreased blood and muscle pH levels making the muscle and blood more acidic. Typically, resting human arterial blood pH is approximately pH 7.4, slightly alkaline, but after strenuous exercise may fall to,  $\sim 7.1$ , while muscle pH decreases to,  $\sim 6.8$ . Buffers such as  $NaHCO_3$  (and sodium citrate) will increase the buffering capacity, according to the dosage, by increasing the pH to 7.5 (McNaughton, 2010). Current study suggests that the ability to maintain high-intensity exercise depends mainly on the capacity to minimize raises in these hydrogen ion concentrations ( $H^+$ ) (Robergs, Hutchinson, Hendee, Madden & Siegler, 2005). Earlier studies have concluded that the boost in hydrogen ions ( $H^+$ ) and a decline in pH hamper aspects of performance such as power output and fatigue by a disturbance of contractility within the muscle (Lavender & Bird, 1989; Robergs, 2005). Particularly, studies have revealed that raised hydrogen ions ( $H^+$ ) in blood and muscle could slow up calcium release from the sarcoplasmic reticulum plus restrain the interaction between actin and myosin (McNaughton & Cedaro, 1991; Requena et al., 2005).

This process, however, stimulates extracellular buffering mechanisms, of which bicarbonate is one of the most effective agents (McArdle et al., 2009). Four basic mechanisms are exist which are known to alter blood and muscle pH. Firstly, bicarbonate can directly buffer the hydrogen ions quickly in seconds. Second, lactate generated from high intensity energy metabolism diffuses into the blood stream as transporting a hydrogen ion ( $H^+$ ) out of the muscle cell at the same time. After this, bicarbonate then removes hydrogen ions through ventilation. In reaction to this accumulation, bicarbonate binds with the free hydrogen ions

(H<sup>+</sup>) forming carbonic acid (H<sub>2</sub>CO<sub>3</sub>) and eventually transports the residual CO<sub>2</sub> to the lungs where it and water are then exhaled and removed (McNaughton et al., 2008). At the last stage, the kidneys excrete hydrogen ions (H<sup>+</sup>) as fixed acid and work on a long-term basis to maintain acid-base balance.

“The relationship between performance and levels of HCO<sub>3</sub><sup>-</sup> and CO<sub>2</sub> in the blood was demonstrated; hence the effect of H<sup>+</sup> is obvious: H<sup>+</sup> accumulation is a limiting factor in the usage of nonoxidative sources of energy” Verbitsky, Mizrahi, Levin and Isakov (1997, p. 337). This study also showed that NaHCO<sub>3</sub> ingestion clearly results in a more alkaline extracellular environment. Furthermore, the H<sup>+</sup> buffer appears in plasma but does not enter muscle. The ergogenic effect is supposed to be mediated by greater H<sup>+</sup> removal from working muscle fibres to delay or weaken the fall in intramuscular pH (Cairns, 2006). Verbitsky (as cited in Cairns, 2006, p. 287) also stated that, similar to other studies, “there is evidence suggesting that bicarbonate can act on muscle to improve contractile performance”.

Research undertaken by Stephens, McKenna, Canny, Snow and McConell (2002), also found similar positive effects of increased plasma HCO<sub>3</sub><sup>-</sup> concentrations after NaHCO<sub>3</sub> loading. Stephens et al., (2002) examined the effects of sodium bicarbonate intake on muscle metabolism during intense endurance cycling lasting for approximately 60 minutes. They found small but significantly greater ( $p < 0.05$ ) treatment effect for Sb condition than the placebo. Muscle H<sup>+</sup> concentration was lower ( $p < 0.05$ ) at rest, at 30 min and also at the end of the exercise (~ 60 min) in Sb condition, as can be seen in the *Figure 1* below.

**Figure 1.** Muscle  $H^+$  concentration at rest, after 30 min of exercise at  $77 \pm 1\% \dot{V}O_{2peak}$ , and after the performance ride ( $469 \pm 21$  kJ) after ingestion of  $NaHCO_3$  or CON (control). Values are mean  $\pm$  SEM ( $N=7$ ). \* denotes different to CON ( $P < 0.05$ ); † denotes different to REST ( $P < 0.05$ ).

(Stephens, Mckenna, Canny, Snow & Mcconell, 2002)

Intake of alkalinizing agents such as sodium bicarbonate may assist this buffering system through increasing bicarbonate ions ( $HCO_3^-$ ) and consequently raising pH in the blood at the beginning, during and after exercise (McNaughton, 1992; Requena et al., 2005). On the other hand, intramuscular pH and bicarbonate levels remain comparatively the same. In this perspective, the mechanism by which the intake of sodium bicarbonate may boost performance seems to be caused by the increased buffering capacity outside the cell (Requena et al., 2005). Previous investigations have proved that increased extracellular pH and higher bicarbonate levels, after loading of sodium bicarbonate, enhance the removal of hydrogen ions ( $H^+$ ) and lactate from the muscle. This process is the most important determinant for the improving markers of performance, for example, power output, fatigue, and perception of fatigue (Requena et al., 2005). *Table 1* below gives detailed look to the selected papers related with this study between years 1996-2006.

**Table 1.** A summary of some particular studies (in or after the year 1996) related with this study.

Author	Exercise Mode or Sport-Specific Exercise	Dose (g·kg <sup>-1</sup> ·bw <sup>-1</sup> )	Loading Time Before Exercise	Reported Ergogenic Effect
<b>Multiple Bout Exercise</b>				
Bishop, et al., 2004*	Series of five 6-s RS (4:1 work to rest ratio)	0.3	90 min	↑ in total work and ↑ in work and PO in sprints 3-5
<b>Endurance Performance</b>				
Bishop & Claudius, 2005*	Two 36-min “halves” of intermittent field hockey specific activity	0.2 twice	Split at 90 and 20 min	No difference in total work over 72 min; ↑ work performed in 7 of 18 second half sprints
Price, Moss & Rance, 2003*	30-min intermittent cycling	0.3	60 min	↑ average relative PO during maximal sprint efforts
Stephens et al., 2002*	30-min cycling	0.3	90 min	No difference in performance
McNaughton, Dalton, Palmer, 1999b	60-min cycling	0.3	90 min	No difference in total work but maybe used to offset the fatigue process
Potteiger, Nickel, Webster, Haub & Palmer, 1996a ( <i>sodium citrate were used</i> )	~ 60-min (30 km) cycling	0.5	90 min	Decrease in total time (102s)
<b>Chronic Loading</b>				
Douroudos II et al., 2006*	30 s Wingate (0.075 kg·kg <sup>-1</sup> ·bw <sup>-1</sup> )	0.5 for 5 days	None on day of trial	↑ average power in 0.5 g NaHCO <sub>3</sub> only
McNaughton, Strange & Backx, 2000	3 x 30 s Wingate	0.5 for 5 days	None on day of trial	↑ in total work ( <i>p</i> < 0.0001)
McNaughton, Backx, Palmer & Strange, 1999a	60 s cycling	0.5 for 5 days	None on day of trial	↑ in total work ( <i>p</i> < 0.05) and ↑ in peak power

PO = power output, RS = repeated sprint.

\*Adopted from, McNaughton, Siegler and Midgley (2008)

### *Effect of Sodium Bicarbonate loading to the GI Discomfort*

Hespel, Maughan and Greenhaff (2006) argues that gastrointestinal discomfort, mostly cramping, diarrhoea or vomiting, linked with bicarbonate intake can be serious. As Hespel et al. (2006, p. 752) stated, “it is unlikely that the small beneficial effect possibly obtained from bicarbonate intake during the initial stage of a football match could outweigh the risk for gastrointestinal distress in a later stage, usually starting about 1 h after ingestion”. For that reason, researchers did not believe that the sodium bicarbonate can be a sensible supplement in the conditions of football. Although this view is still reasonable, today, many studies proved the effectiveness of chronic and serial loadings and if athletes choose one of these two methods, there is no way to experience any serious negative health effects of Sb (McNaughton & Thompson, 2001; Douroudos II et al., 2006; Barber, 2010).

### *Understanding Physical Demands of Football*

Football is the major sport attraction in the world and compared with the other forms of sport, football is played in every country without any exception (Reilly & Williams, 2003a). The game lasts 90 minutes with additional one to ten minutes extra time for pauses. It also includes two halves evenly divided (45 mins) and between them there is a 15 minutes half-time break for re-hydration and refuelling of the players.

Football has been defined as an open-skill interval activity characterized by high unpredictability inherent to individual and team behaviour between matches and individual players (Ekblom, 1994). Due to the nature of football, the aerobic system is the major energy source (98%) of the body (Bangsbo, 1994). Football can also be described as a multi-sprint sport characterized by short periods of high intensity exercise randomly interspersed with

periods of active and passive recovery played over a relatively extended duration (i.e. 90 minutes).

Aerobic performance is crucial for football players. Analysis of a football match shows that it is estimated that most top-class football players cover a total of about 8–12 km during a game (Maughan & Burke, 2002). In addition to this, average  $\dot{V}O_2$  (oxygen uptake) of elite (women) football players found 77% of  $\dot{V}O_{2max}$  and their heart rate max ( $HR_{max}$ ) reach to 97% which means that match play is physically demanding for most of the players (Krustrup, Mohr, Ellingsgaard & Bangsbo, 2005). Recent data recommends that high-intensity longer-duration performance can benefit from the ergogenic effects of sodium bicarbonate (Castell, Burke, Stear, McNaughton & Harris, 2010).

There are some events in football, which stress both the aerobic and anaerobic metabolic pathways (Metaxas, Koutlianos, Kouidi & Deligiannis, 2005). These numerous explosive bursts are essential in soccer for kicking, tackling, turning, sprinting and changing the ball pressure from the opposition (Wisloff, Helgerud & Hoff, 1998). A study conducted by Bloomfield, Polman and O'Donoghue (2007) concluded that players perform the different types of movement with a range of intensities and players perform frequent turns during movement patterns. They found that there are some differences existing between striker, midfielder and defender in terms of physical demands. According to the same research, it was stated that defenders and strikers could benefit from speed and agility type conditioning whereas midfielders would benefit more from interval running over longer distances in accordance to the findings of this study.

During a football game, or just in regular exercise, the number of  $\text{CO}_2$  concentrations increases in the blood and they need to be eliminated. As  $\text{CO}_2$  is a weak acid, while  $\text{CO}_2$  dissolves in body fluid the removal of  $\text{CO}_2$  leaves the blood more alkaline than normal due to an excess of bicarbonate ions. The kidneys balance this by excreting surplus bicarbonate, so restoring the usual pH level of the blood occurs over several days. The decrease in the body's alkaline reserve leaves the blood with a poorer buffering capacity for tolerating additional acids such as lactic acid diffusing from muscle to blood during exercise (Reilly, 2007). In such conditions, Sb can be considered to be used as a support for poor buffer capacity and it may lead to earn some extra time for players.

### *Conclusion*

Sodium bicarbonate is among the most popular and widely used supplements in the realm of sports and exercise. This literature review has revealed that research suggests that sodium bicarbonate can be used to enhance high-intensity interval performance. As most of the previous research suggests, sodium bicarbonate has been found to act as a buffer to facilitate increasing the blood pH. Previous research suggests that appropriate oral supplementation of 0.2-0.6 grams per kg body weight in acute or serial days loading of sodium bicarbonate can benefit high intensity performance by means of accelerating hydrogen ion efflux out of the working muscle. Considering that this is the only study that is known to have examined the effect of Sb on a 90 minutes football specific exercise session, more research is necessary to further understand the ergogenic effect of Sb on long duration events. In conclusion, since it is known that acute Sb supplementation showed improvement on a 72 minutes exercise event, serial loading of Sb may also improve sprint and endurance performance during a much longer exercise event.



## **Chapter 3**

### **Methods**

#### *Overview*

The purpose of this study was to determine whether a short-term (2 days) supplementation of sodium bicarbonate ( $\text{NaHCO}_3$ ) would enhance the well-documented research of bicarbonate loading on repeated sprint performance and also the time to exhaustion when tested on a simulated football match. In this study a double-blind, randomized, crossover study design was used. All subjects completed three conditions, except the control condition, the others included test drinks followed by a 5-day washout period between these two conditions (see Figure 2 for detailed supplementation diagram):

1) control, 2) placebo/drug and 3) placebo/drug.

During each condition, sprint times, exhaustion times and rating perceived exertion (RPE) were assessed. In addition to this, before the test day, gastro intestinal (GI) distress questionnaires were used to assess the number and severity of symptoms during the supplementation period.

#### *Participants*

In this study, seven male, healthy, university football team players (age  $24.0 \pm 1.6$  years, height  $1.75 \pm .04$  m, weight  $74.7 \pm 9.5$  kg and body mass index  $24.3 \pm 2.3$   $\text{kg/m}^2$ ) volunteered (see *Table 2* below). The university where the tests for study were conducted is the Eastern Mediterranean University (EMU), which is a local university in Famagusta, Cyprus. University students gave their written informed consent to participate in the study (see Appendix B) and an approval for the study's procedures was granted by the research ethics committee of the University of Chester. In addition to this, participants were informed

(both verbally and in writing) of the study requirements, benefits and risks (see Appendix A, for participant information sheet) before being giving the written informed consent form by the researcher prior to commencement of the study in order to be sure that each volunteer participant had fully understood and filled in the consent form before joining the research. Also, all participants were assigned a number by which they were referred to in any report or in statistical analysis. This ensured confidentiality and anonymity.

**Table 2.** Subject Characteristic. Values are mean (SD).

Variables	Mean	Std. Deviation	Minimum	Maximum
Age (yrs)	24.00	1.633	22	27
Height (m)	1.7514	.0452	1.69	1.81
Weight (kg)	74.786	9.583	59.6	90.2
BMI (kg/m <sup>2</sup> )	24.319	2.319	20.1	27.5
(N = 7)				

None of the subjects were involved in any form of nutritional supplementation that may have compromised the administration of the NaHCO<sub>3</sub>.

#### *Design of the Study*

The study consists of four sessions of exercise tests and involves taking test beverages according to the researcher's directions and filling in the questionnaire forms regularly. Exercise tests: the first one is a Bleep test (see Appendix I) in which participants need to run over 20 metres distance and this test will show the participants' predicted maximal oxygen uptake. Other sessions are all LIST tests, in which participants will be asked to walk/jog/run/sprint over 20 metres distance again and rest between the periods during 90

minutes duration. In addition to this, subjective ratings of perceived exertion was recorded on a 15 point (6-20) Borg's RPE scale (Borg, 1998) after finishing each period in LIST (Nicholas, Nuttall, & Williams, 2000).

Before the tests, subjects will be required to consume no food or beverages (other than water) 2 hours before testing, and will be asked not to consume alcohol or perform vigorous exercise in the 24 hours before testing. Furthermore, it is required to consume similar diets and sleep similar hours in the 2 days before the test.

### *Equipment*

A clear flat area for conducting the test (at least 30m long) was required and the university's sports hall was used for the test venue with permission in specific hours. Timing gates were planned to be used for measuring the sprint times, but due to technical matters, a digital stopwatch (1/100 second chronograph, JUNSO Digital Stopwatch JS-307) was used instead. All devices and test venues supplied from Eastern Mediterranean University (EMU), please see letter of permission in Appendix C.

### *Preliminary Supplementation Test*

On day two, participants were asked to drink a single dose (0.5g/body weight/4, which was equal to one of the four doses in any of the loading days) and fill in a questionnaire form and return it to the researcher to consider if any of the players were experiencing a negative feeling or health problems before the real loading phase started.

### *Supplementation Procedure*

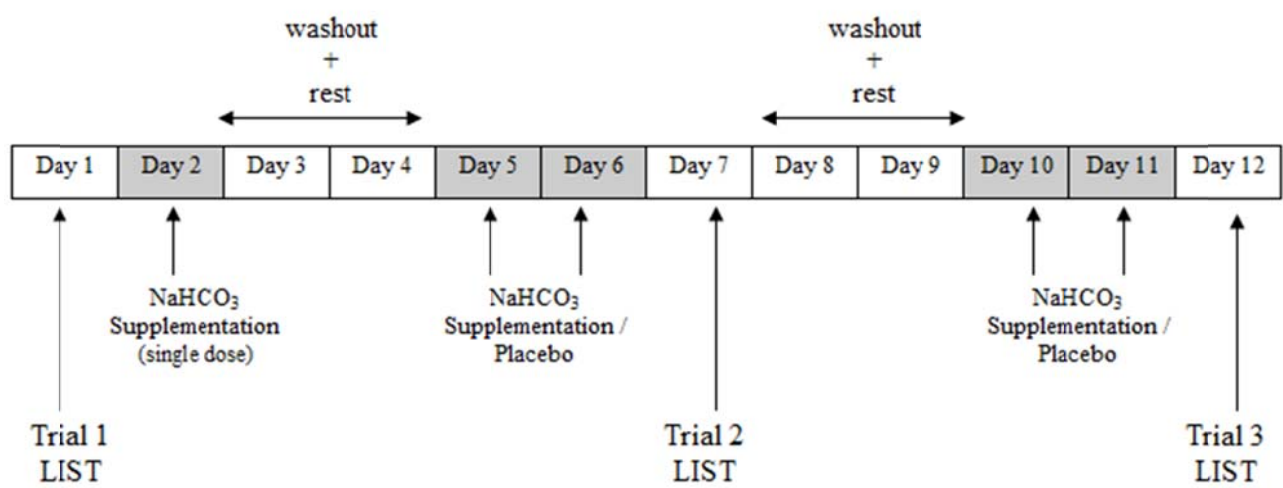
In this study, a randomized, cross-over, double-blind, placebo-controlled experimental design will be adopted to determine the efficiency of short-term loading of  $\text{NaHCO}_3$  supplementation using the Loughborough Intermittent Shuttle Test (LIST). An overview of the experimental protocol is presented in Figure 2 below.

Sample size was expected to be around 10-15 but due to withdrawal of some subjects it was decreased. On the other hand, even though this number looks very small, past studies also recruited 8-10 participants for their sodium bicarbonate researches (McNaughton et al., 1999; Siegler et al., 2010; McNaughton, Dalton, & Palmer, 1999). Participants need to be football players. The amount of daily dose was 0,5g/kg body weight and given to the participants in four equal portions over the day which will lasts for two days. For estimating the weight of participants were ready in the morning of the Bleep test with an empty stomach. Researchers weighed all participants with a digital scale.

All test drinks consisted of 500ml water and two tablespoons of concentrated unsweetened juice for improving the taste (without calories). As in the study of Price, Moss and Rance (2003), sodium chloride ( $\text{NaCl}$ ; 0.045 g·kg<sup>-1</sup>) was used for placebo drinks to be given the same taste as the bicarbonate drink. After participants consumed their test drinks, they filled in the gastrointestinal symptom questionnaire just after and 60 minutes after, ingestion, and this procedure was validated for every portion they consumed in a day (see Appendix D for the GI distress questionnaire).

As can be seen in the diagram below, the study started with a LIST test, but without any test drinks as a means of being a control trial. On the second day, a preliminary supplementation

test was applied to all participants and then given two days free from the test drink and exercise to get players ready for the loading phase and then test trials. As can be seen in the *Figure 2* below, when one group taken the sodium bicarbonate loading on days 5-6 there was a due to the cross-over desing of the study.



**Figure 2:** Diagrammatical Representation of Experimental Protocol.

*Estimation of Subjects’ Training Status*

The training status has an important role in sports science studies, not just because treatments may have a different effect on athletes who have a different training status, but also for understanding which types of athletes can benefit from the results of the study. Because of this, in this study a progressive shuttle run test, also known as a Bleep test, was applied to the subjects (Ramsbottom, Brewer, & William, 1998), two days before the trial 1. This test consists of shuttle running between two markers placed 20 metres apart at increasingly fast speeds to the feeling of exhaustion (see Appendix I). Tests took place in a sports hall and a laptop was used to play the appropriate audio for conducting the test. According to the

exhaustion times of the subjects, they were given a level and this level also has an equivalence value as predicted  $\dot{V}O_{2\max}$  (maximal oxygen uptake) value. In this study, subjects' predicted  $\dot{V}O_{2\max}$  values are shown in the *Table 3* below.

**Table 3.** Predicted maximal oxygen uptake values for the progressive shuttle run test.

Code of Subject	Level	Shuttle	Predicted $\dot{V}O_{2\max}$
1, 6, 7	10	4	48.0
2, 3	10	6	48.7
4	11	6	51.9
5	11	8	53.1

(Ramsbottom, Brewer, & William, 1998)

The nature of the football game is a prolonged intermittent exercise, which is partly intense and partly passive. Although football includes both aerobic and anaerobic activity, the main amount of effort comes from aerobic power, (Bangsbo, as cited in Reilly, 2007, p.155). It was found that the average values of  $\dot{V}O_{2\max}$  for top-level soccer players are likely to be high, which is changing between 55-70 ml kg<sup>-1</sup> min<sup>-1</sup> but needless to say that is not as high as long distance runners or skiers, (Reilly, 2007). When players are at their peak fitness or at the highest level of their performance, the values are found around the top of this range. A study conducted by Reilly and Doran (as cited in Reilly, 2007, p.156) concluded that the average value of the maximal oxygen uptake of the football players was 59 ml kg<sup>-1</sup> min<sup>-1</sup>, depending on measurement of over 500 professional players. The subjects'  $\dot{V}O_{2\max}$  capacity in this study expected between 48-53.1 ml kg<sup>-1</sup> min<sup>-1</sup> and the average was 49.4 ml kg<sup>-1</sup> min<sup>-1</sup>. Due to all these values, it can be considered as a good level for unprofessional football players when

compared with the professional players' values but it is definitely an insufficient level for professionals.

### *Loughborough Intermittent Sprint Test (LIST)*

This test was created by Nicholas, Nuttall & Williams, (2000) for an alternative test for understanding the physiological and metabolic effects of any food, drink or ergogenic aids to intermittent high-intensity exercise. LIST tests consist of two parts. Part A includes five 15 minutes (total 75 minutes) exercise sessions, but in total with rest times, Part A was equal to 90 minutes duration, as in a regular football game. For Part B, there is not a specific duration and it can be assumed that Part B as an extension time for a football match.

The participants are required to run between two lines, 20m apart, at various speeds related to estimated (or predicted) individual maximal oxygen uptake. The running and walking speeds during each 20m of the test were dictated by an audio signal from a laptop and special care was shown for participants to hear the signal easily inside the hall. Sprint times were measured in one direction over the first 15 metres using a stop-watch.

For a detailed look at Part A, there is a fixed duration (see *Figure 3* below) consisting of five 15 minute exercise periods separated by three minutes of recovery. The pattern of exercise for Part A was as follows:

- 3 x 20m at walking pace
- 1 x 20m at maximal running speed
- 4 s recovery
- 3 x 20m at a running speed corresponding to 55% of individual  $\dot{V}O_{2\max}$
- 3 x 20m at a running speed corresponding to 95% of individual  $\dot{V}O_{2\max}$

This model was designed very similar to the activity pattern typically recorded for soccer a match (Reilly & Thomas, 1976, as cited in Nicholas et al., 2000). These exercises were repeated eleven times in every five period of Part A.

For a detailed look at Part B, there was an open-ended period of intermittent shuttle running, designed to exhaust the players within the 10 minutes (Nicholas et al., 2000). The participants were required to run at speeds equivalent to 55% and 95% of predicted  $\dot{V}O_{2\max}$ , the speed changes every 20 metres. This pattern of repeated exercise should continue until the participants were unable to maintain the required speed (see *Figure 3* below).

**Figure 3.** Schematic representation of the LIST protocol (Adopted from Nicholas, Nuttall & Williams, 2000).



### *Potential Risk or Adverse Effects*

There have been some side effects seen regarding gastrointestinal problems in some studies. These effects are not serious and are not long-term (Maughan & Burke, 2002). There were no significant gastrointestinal side-effects found when sodium bicarbonate was given in four portions a day (Barber, 2010). Also, assessment of functional gastrointestinal disorders will be done by using the GI-Tolerability Assessment Questionnaire, see Appendix D (Cameron, McLay-Cooke, Brown, Gray, & Fairbairn, 2010).

### *GI-Symptoms Assessment Questionnaire*

To assess the complications, if there were any, of the acute GI (gastro-intestinal) discomfort, subjects completed a questionnaire at baseline and at 60 minutes after ingestion of the test drinks. The questionnaire was adopted from a research conducted by Cameron, McLay-Cooke, Brown, Gray and Fairbairn (2010) and it consists of two questions (see Appendix D). For the second question, it consisted of nine 100-mm visual analogue scales (VASs). These VASs are anchored at each end with *no symptom* on the left hand side and *severe symptom* on the right hand side. Participants were asked to rate the severity of their symptoms. If they experienced no symptoms they circled the appropriate words, for example, *no stomach cramping*. If they were experiencing some symptoms, they indicated their overall rating by placing a vertical mark on the line. The VASs were used to measure symptoms of nausea, flatulence, stomach cramping, belching, stomach ache, bowel urgency, diarrhoea, vomiting and stomach bloating (Cameron et al., 2010).

### *Statistical Analysis*

SPSS (Statistical Package for the Social Sciences) was used for statistical analysis of this study. Where data was subjected to, and passed, the normality tests, a one-way (repeated measures) ANOVA was selected to determine the sprint times, exhaustion times and RPE scores, as there are three repeated trials with same participants (Coakes & Steed, 2007). Besides these, for analysing the severity ratings of the GI distress questions, a T-Test for related samples (paired T-Test) was conducted. Dependent variables of the study are exhaustion time, sprint time and RPE score, which are measured to see if their values will change with, and without, sodium bicarbonate supplement. Independent variables are conditions, which are baseline, placebo and sodium bicarbonate conditions.

Due to the crossover nature of the design, each subject underwent each trial allowing a comparison of trial means to be done 'within subject'. In every period of LIST, each subject underwent eleven sprints (repeated measurements) at baseline and also after the application of other two conditions (Placebo and Sb). The purpose was to look for an interaction to see if there was a significant difference within the mean sprint times in different conditions but in the same period of time (e.g., mean sprint time of 1<sup>st</sup> period in control & Placebo and Sb). This method was also conducted for exhaustion times and RPE scores.

For measuring the sprint times, exhaustion times and RPE scores of the three trials, normality was tested and if the assumption of a normal distribution was not violated the figure was normally distributed and after this a one-way (repeated measures) ANOVA multiple paired *t*-tests performed. If the assumption of a normal distribution was violated a Friedman test was adopted, which is a non-parametric statistical test and then multiple Wilcoxon tests were conducted to see where the difference lies.

For measuring the severity ratings of the GI distress question, which was applied in two conditions (Placebo and Sb), paired samples (repeated measures)  $t$ -tests were performed. If the assumption of a normal distribution was not violated the figure was normally distributed and after this a paired samples  $t$ -test was performed. If the assumption of a normal distribution was violated a Wilcoxon test was adopted, which is a non-parametric approach.

Bonferroni adjustment was employed because multiple tests were being conducted on the same subjects (Coakes & Steed, 2007). The level of significance was set at  $p < 0.17$  for sprint times, exhaustion times and RPE scores. For the GI distress questionnaire, Bonferroni adjustment was employed again and the level of significance was set at  $p < 0.25$ .

## Chapter 4

### Results

#### *Performance Measures*

The *Table 4* below shows the approximate speed and relative time for different exercise modes in the LIST. In addition to this, Nicholas, Nuttall and Williams, (2000) stated that to finish the one cycle of intermittent shuttle running lasts for  $81.2 \pm 0.4$  seconds. In the same investigation, researchers estimated that the distance covered for Part A was  $11.1 \pm 1.8$  km and for the both parts (Part A and B) was 12.4 km. All these measures were expected to be very similar in this study.

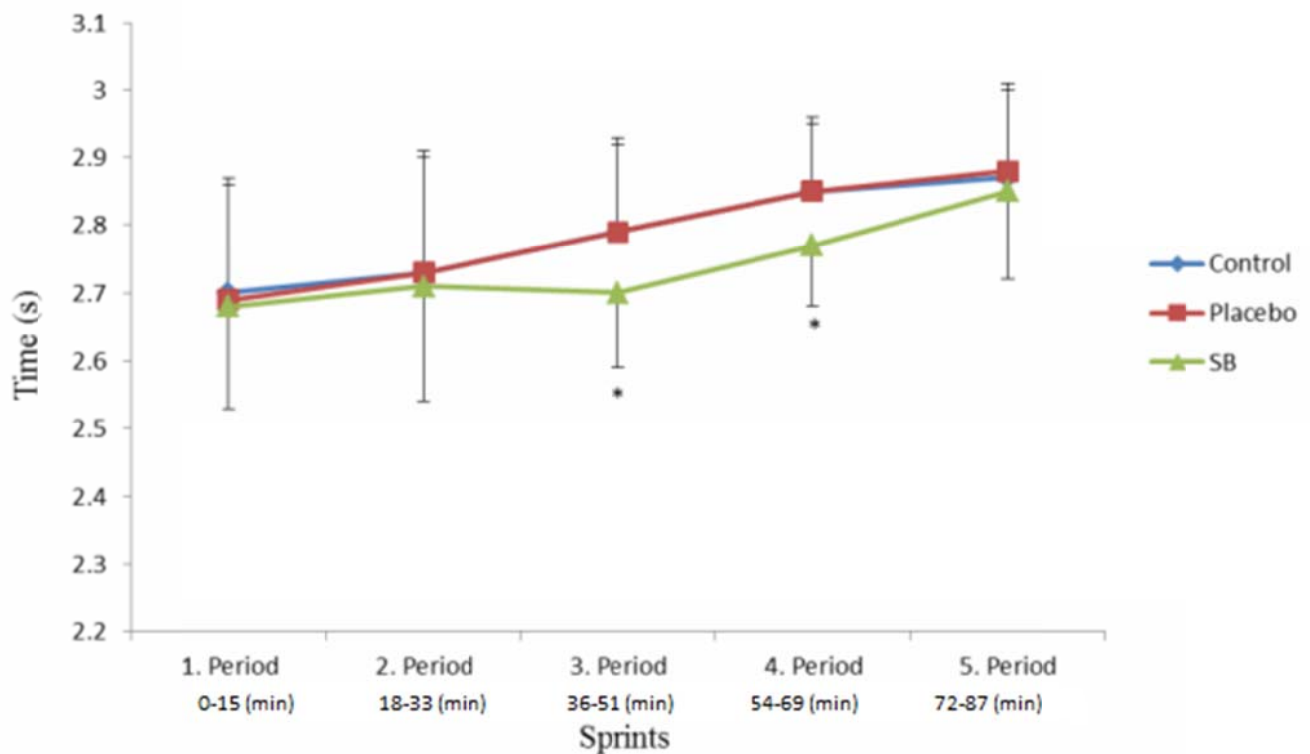
**Table 4.** Walking and running speeds and relative time spent in each exercise mode during the LIST.

Exercise mode	Speed (m/s)	Relative time (%)
Walking	1.54 (5.5 km/h)	48.1
Sprinting	6.2 (22.3km/h)	3.0
Recovery	-	4.9
Jogging (%55 VO <sub>2max</sub> )	3.0 (10.8km/h)	24.7
Cruising (%95 VO <sub>2max</sub> )	3.83 (13.8 km/h)	19.3

Adopted from Nicholas, Nuttall & Williams, 2000.

## Sprint Performance

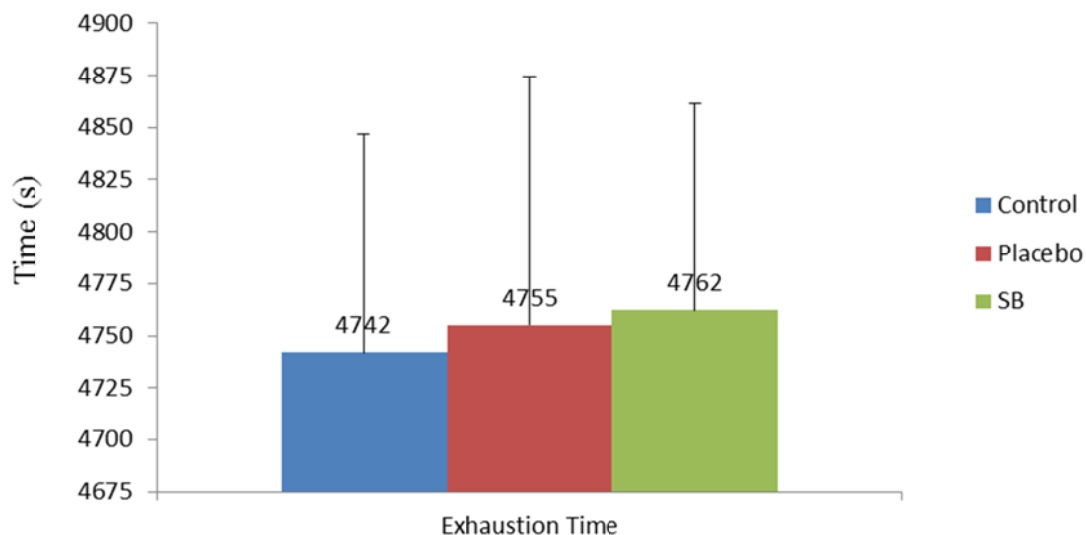
There were significant differences found between the sodium bicarbonate condition and each of the other conditions, (Control and Placebo) in the 3<sup>rd</sup> and 4<sup>th</sup> periods (all  $p = .000$ ). For the 1<sup>st</sup>, 2<sup>nd</sup> and 5<sup>th</sup> periods, there were no significant differences observed between any conditions (all  $p > .019$ ). This result also shows that there was an increase in sprint performance particularly between 36-69 minutes (including rest times) as shown in the *Figure 4* below. As there were eleven sprints in each of the five periods, the time values of the periods below were estimated as a mean of these eleven sprints.



**Figure 4.** Mean sprint times of each condition (Control, Placebo and Sb). The times given included three minute rests.

## Exhaustion Time

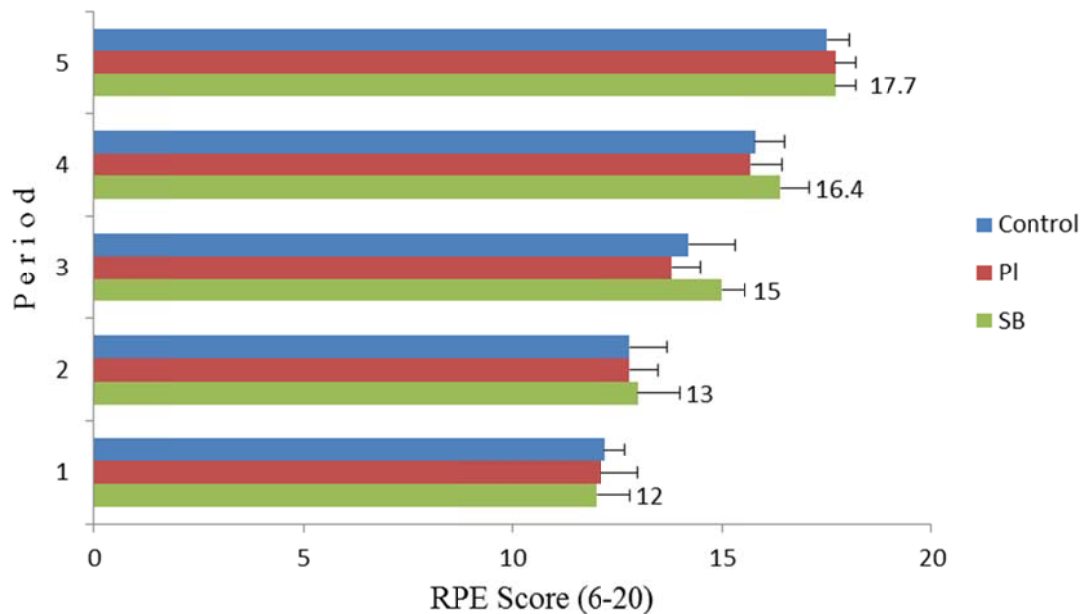
Exhaustion times were similar during each condition in Part B of the LIST. There were no significant differences found for exhaustion times within in the subjects (  $p = 0.292$ ). As can be seen in the *Figure 5* below, the maximum exhaustion time difference between conditions was recorded as twenty seconds and the minimum was seven seconds according to the mean exhaustion values of each condition. The major difference was just 0.4% (20 s) found between control and sodium bicarbonate conditions, which was not a significant improvement. When the mean exhaustion times were converted to minutes they were equal to 79min 2s for control trial, 79min 15s for placebo trail and 79 min 22s for sodium bicarbonate trial. These values were not included in the three minutes rest times between the periods, which was equal to fifteen minutes in total, also the same as the break time of a regular football match.



**Figure 5.** Mean exhaustion times (Part A+B) of the subjects during the different conditions.

### Rating of Perceived Exertion

For Rating of Perceived Exertion (RPE), as shown in the *Figure 6* below, there were no significant differences observed between each of the conditions during Part A (all  $p > .020$ ). All RPE ratings raised gradually, which was expected as a nature of feeling fatigue. RPE scores initially increased from values of  $12 \pm 1$  to the  $18 \pm 1$  after the 5<sup>th</sup> period of Part A. There was no RPE score taken for Part B because all the subjects tested to feel the exhaustion, which means at that point all RPE scores were equal to 20.

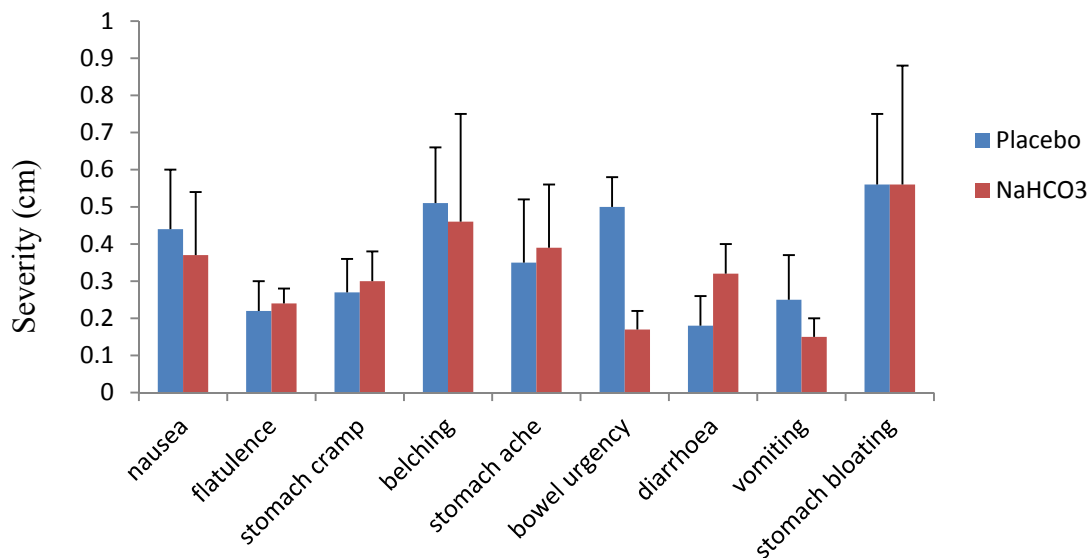


**Figure 6.** Mean of the RPE scores during Part A (0-90 min) of the LIST test.

### Severity of Acute GI Discomfort

#### Baseline (Time 0) Between Placebo & NaHCO<sub>3</sub>

For severity of acute GI discomfort between Placebo and Sb, there were no significant differences found at baseline (Time 0) (all  $p > .066$ ). *Figure 7* below shows that the measurements of each condition were close to each other except for bowel urgency, however, there wasn't a significant difference due to the small values.

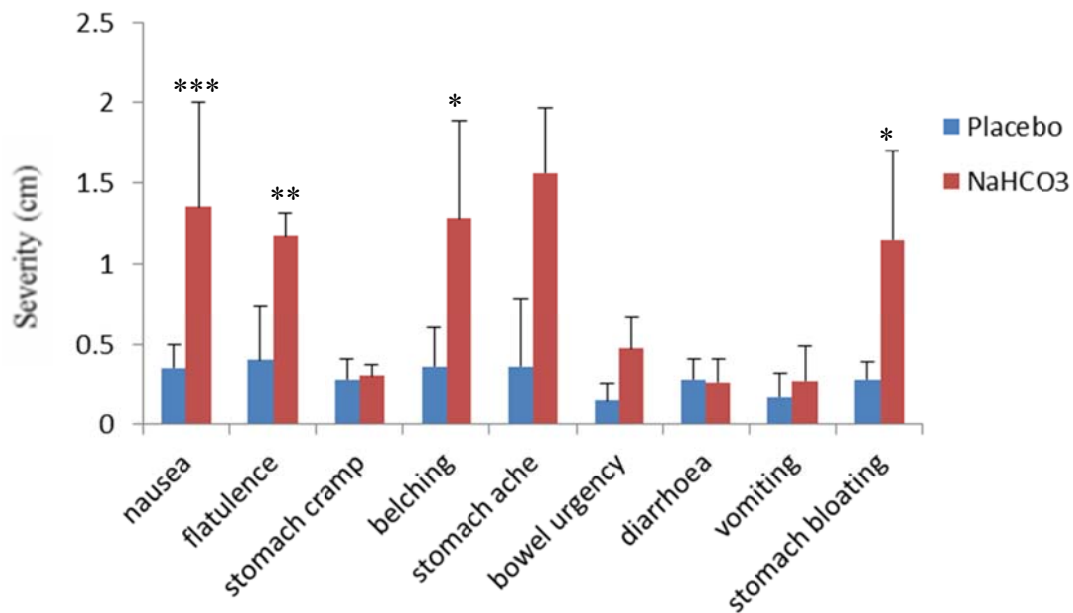


**Figure 7.** Severity of gastrointestinal discomfort symptoms (0-10 cm) reported at just after ingestion of Placebo and NaHCO<sub>3</sub>,  $N = 7$ . Values are  $M \pm SD$ .



### 60 Min After Ingestion Between Placebo & NaHCO<sub>3</sub>

For severity of acute GI discomfort between Placebo and Sb, there were significant differences found at 60 min after ingestion between nausea ( $p = .001$ ), flatulence ( $p = .005$ ), belching ( $p = .012$ ) and stomach bloating ( $p = .012$ ). *Figure 8* below shows that for these measurements the values were significantly greater.

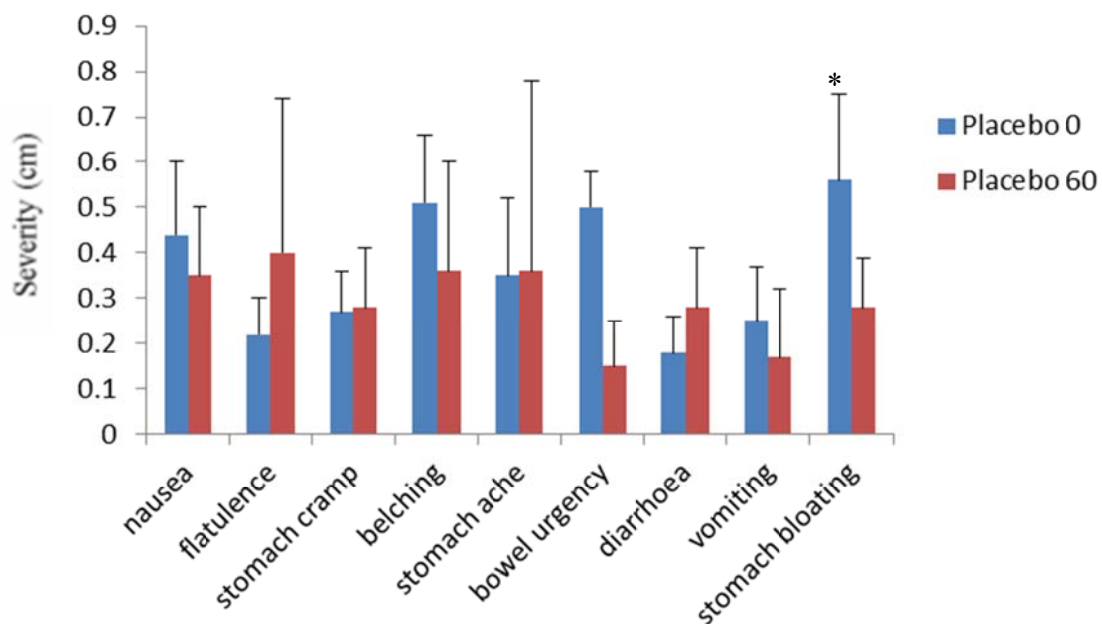


**Figure 8.** Severity of gastrointestinal discomfort symptoms (0-10 cm) reported 60 min after ingestion of Placebo and NaHCO<sub>3</sub>,  $N = 7$ . Values are  $M \pm SD$ . \* $p < .025$ . \*\* $p < .01$ . \*\*\* $p = .001$ .

### Changes From Baseline (Time 0) to 60 Min After the Ingestion Between Placebo & Placebo

For severity of acute GI discomfort between Placebo and Placebo, there were no significant differences found between these two time periods except for stomach bloating.

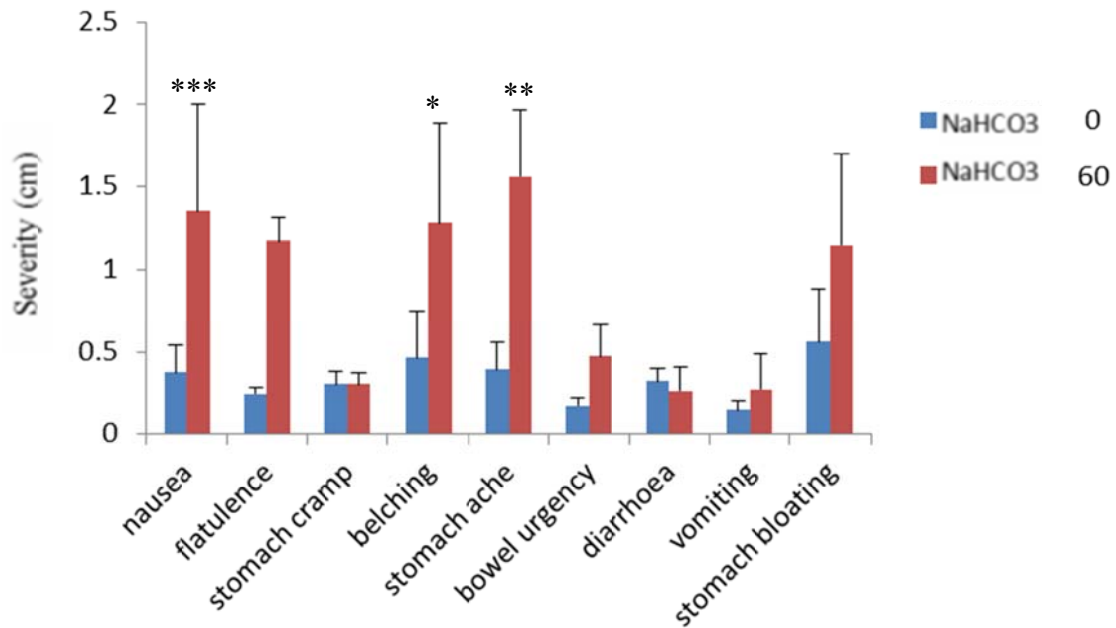
Figure 9 below shows how the measurements change over the time between placebo conditions. Only for stomach bloating were values significantly greater.



**Figure 9.** Severity of gastrointestinal discomfort symptoms (0-10 cm) reported just after and 60 min after ingestion of Placebo,  $N = 7$ . Values are  $M \pm SD$ . Values are  $M \pm SD$ .  $*p < .025$ .

### Changes From Baseline (Time 0) to 60 Min After Ingestion Between NaHCO<sub>3</sub> & NaHCO<sub>3</sub>

For severity of acute GI discomfort between Sb and Sb, there were no significant differences found 60 min after ingestion for nausea, belching and stomach ache. *Figure 10* below shows how sodium bicarbonate ingestion changed between the two time periods.



**Figure 10.** Severity of gastrointestinal discomfort symptoms (0-10 cm) reported just after and 60 min after ingestion of NaHCO<sub>3</sub>,  $N = 7$ . Values are  $M \pm SD$ . \* $p < .025$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

## **Chapter 5**

### **Discussion**

The goal of this study was to examine whether the sodium bicarbonate supplementation in a football specific exercise test would improve markers of exercise performance and fatigue compared to placebo conditions.

The main findings were:

- 1) Sodium bicarbonate loading produced slightly (3.2%) but significantly greater ( $p = .000$ ) sprint performance than the placebo in some periods of the exercise session (LIST).
- 2) Two days of Sb supplementation was sufficient to increase repeated sprint performance compared to the placebo trial.

However, in contrast to hypotheses, no benefits from supplementation were observed for time to exhaustion and perception of fatigue (RPE).

A novel finding in the current study is an apparent difference in exercise performance of sprint times during some periods (3 and 4) of LIST when the sodium bicarbonate supplementation was applied. The Sb supplementation resulted in approximately 3.2% greater mean sprint time than the placebo condition during the 3<sup>rd</sup> period of LIST. Although mean sprint time values in the 1<sup>st</sup>, 2<sup>nd</sup> and 5<sup>th</sup> periods were not significantly different from the placebo and control trial, the sprint times in the 3<sup>rd</sup> and 4<sup>th</sup> periods of Sb supplementation demonstrated the greatest attenuation of decline in mean sprint time values over the eleven repeated sprints for each period. Furthermore, Sb also produced only 0.4% (20 s) greater mean time to exhaustion value than the placebo, which is not significant ( $p = 0.292$ ).

Although this was a sufficient time to win the 30k road race, it is not a notable value for a football game even though it lasts around 90 minutes.

It was hypothesized that since sodium bicarbonate works in acute or chronic loading methods and that they have similar effects in improving repeated sprints. In chronic loading, there would be an additive effect, not on exercise performance maybe, but, on the GI comfort of athletes when compared to acute loading and also less loading time when compared to chronic loading with conducting serial loading. When examining the mechanism of sodium bicarbonate, research suggests that they all aid in repeated sprint performance, primarily through increasing bicarbonate stores as mentioned in the literature review chapter.

Buffering capacity is enhanced during sodium bicarbonate supplementation, due to the tapping of bicarbonate stores in the blood. During high intensity exercise, accumulation of hydrogen ions in the muscle results in decreased blood and muscle pH (Mero, Keskinen, Malvela & Sallinen, 2004). Research suggests that this decrease in muscular pH resulting from accumulation of hydrogen ions ( $H^+$ ) hinders aspects of performance such as power output and fatigue by an interruption of contractility within the myofilaments in the muscle (Lavender & Bird, 1989; Robergs et al., 2005). It is thought that by increasing our bicarbonate stores from sodium bicarbonate supplementation, this would allow for a greater efflux of hydrogen ions out of the muscle cell therefore decreasing fatigue and power output declines. Even though the exact mechanism of action remains unclear for sodium bicarbonate, it has been shown to increase markers of performance (Bishop & Claudius, 2005; McNaughton 1992, 1999a, 1999b, 2001, 2008; Siegler, Keatley, Midgley, Nevill & McNaughton, 2007).

### *Performance Measures*

In Sb trials, improvement of mean sprint times in the 3<sup>rd</sup> period ( $p = .000$ ) and 4<sup>th</sup> period ( $p = .000$ ) were approximately 3.2% and 2.8%, respectively, greater than the placebo and control trials. These values are only valid for between 15 metres running distance and it is quite possible to improve these numbers with a longer distance on the football pitch. Today the exact measurements of a football pitch are fixed. In order to standardize the size of the football pitch for international matches, the IFAB (International Football Association Board) has decided to set a fixed size of 105m long and 68m wide (instead of a minimum and maximum length - from 100m to 110m - and a minimum and a maximum width - from 64m to 75m - (FIFA, 2008). According to these measurements, the distance between corner to corner reaches 125 metres and this makes it possible for 60 metres sprinting in the game. In this study it was found that for 15 metres sprint Sb supplementation can improve performance approximately 3.2% (equal to  $\sim 0.09$  s) and this means that for longer sprints, such as 60 metres, in the match the performance improvements could be better.

It is believed that decreased amounts of blood  $H^+$  concentrations could be the main reason for sprint performance improvement. It was stated before that elevated amounts of  $H^+$  concentrations cause a decrease in blood and muscle pH levels making the muscle and blood more acidic. As recent research found that the capability to maintain high-intensity exercise depends largely on the ability to minimize increases in these hydrogen ion concentrations (Robergs et al., 2005) it can be assumed that placebo and control group blood  $H^+$  levels were higher than the Sb group and that is why the difference occurred in these periods.

“This hyperventilation raises the amount of  $CO_2$  blown off from blood passing through the lungs. As  $CO_2$  is a weak acid when dissolved in body fluid the elimination

of CO<sub>2</sub> leaves the blood more alkaline than normal due to an excess of bicarbonate ions. The kidneys compensate by excreting excess bicarbonate, so restoring the normal pH level of the blood over several days. The decrease in the body's alkaline reserve leaves the blood with a poorer buffering capacity for tolerating additional acids (such as lactic acid diffusing from muscle to blood during exercise" (Reilly, 2007, p. 138).

That is the physiological explanation of how increasing the pH with sodium bicarbonate helps to increase performance, and also this procedure opens the door for using Sb as a recovery supplement to speed up this process.

On the other hand, it is difficult to explain why significant ergogenic effects were only observed in the stated periods (3<sup>rd</sup> and 4<sup>th</sup>), which corresponds to a 36-69 minutes time window in the test, without having any blood analyses of blood bicarbonate, lactate and pH levels. But it is possible to predict the process in general. It is known that in order to utilize the extra buffering capacity in the blood, the H<sup>+</sup> levels in the blood should exceed the capacity of the body's buffering system and as a result fatigue occurs. It is assumed that in the 1<sup>st</sup> and 2<sup>nd</sup> periods, the H<sup>+</sup> levels in the blood were still under the specific level at which the body can easily cope with it and sustain the balance of pH in the blood. In addition to this, the process for the 5<sup>th</sup> period could be the reverse of this. At this stage, after almost 70 minutes, the extra buffering support from Sb was not able to decrease the hydrogen ion concentrations sufficient as before, therefore the pH of the blood went higher and the performance started to decrease. Even though the pH levels could still be lower than the other conditions, this was not enough to make a significant difference between sprint performances.

In the present study, there was no effect of  $\text{NaHCO}_3$  ingestion to the exhaustion performance after 90 min of intensive intermittent exercise session. This is perhaps understandable because  $\text{NaHCO}_3$  had no effect on muscle glycogen use, muscle lactate levels or other measured muscle metabolites, and only a small effect on muscle hydrogen ion concentration. Indeed, several investigations also found no effect of induction of a metabolic alkalosis on prolonged intense exercise performance (Hooker, Morgan & Wells, 1987; Schabort, Wilson & Noakes, 2000). Schabort et al. (2000) found that sodium citrate ingestion had no effect on time to complete a 40km variable-intensity time trial (~60 min) in well-trained endurance athletes.

Induced alkalosis via supplementation may enhance performance in short duration, high intensity exercise by either reducing the intramuscular  $[\text{H}^+]$  or by improving the buffering capacity of the tissues (Heigenhauser & Jones, 1991 cited in Potteiger, Webster, Nickel, Haub & Palmer, 1996b). Since competitive endurance racing is performed at intensities that result in a significant amount of blood and muscle lactate production, the use of buffering agents (sodium bicarbonate and sodium citrate) have potential to enhance endurance exercise performance (Potteiger et al., 1996b). For conclusive results regarding whether Sb works for longer durations than 30-60 minutes, there should be more studies to understand the detailed mechanism. Hooker et al. (1987) have found no ergogenic effect of sodium bicarbonate ingestion on times to exhaustion and also for lactate concentration in a group of 10km runners during a treadmill run to exhaustion at 89% of  $\dot{V}\text{O}_2\text{max}$ . However, it is uncertain whether an alkalotic state was achieved in these subjects, because the bicarbonate was administered only 30 min prior to the treadmill run and no blood gas data were reported (Potteiger et al., 1996b). On the other hand, it is still worth to test the Sb on prolonged exercises because Sb is also able to raise the maximal oxygen uptake levels which may be helpful for improving the



exhaustion times. To give an example, in a study of Cho, Chung, Park, and Choi (1990), during graded exercise,  $\dot{V}O_{2\text{max}}$  values increased significantly by 5.5 % (3.51 ml/kg·min<sup>-1</sup>) under the Sb condition.

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In the present study, however, RPE was similar between trials and does not support the results of Swank and Robertson (1989) even though it is believed that alkalosis had been achieved before exercise as a result of improved sprint times. Mean RPE scores of all conditions were very similar and there were no significant differences between conditions.

Normally maximal oxygen uptake tests should be performed to monitor the fitness levels of the subjects, but due to insufficient facilities, a Bleep test was used to determine the players' maximal oxygen uptake. Even if it is not completely correct, it is an easy and helpful tool in the training programme setting and for player follow-up during the playing season. But for precise values, it is necessary to use ergospirometry to accurately estimate aerobic capacity in soccer players (Metaxas et al., 2005). Reilly (2007) argued that while  $\dot{V}O_{2\text{max}}$  alone does not provide success in soccer, there is a lowest threshold at about 60 ml kg<sup>-1</sup> min<sup>-1</sup> and players falling below it may be unsuccessful in always performing well at the highest level of professional play. The players who participated in this study have ~ 50 ml kg<sup>-1</sup> min<sup>-1</sup> which should be enough for amateur players.

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It has been observed that splitting the loading into four equal doses over the two-day period definitely helped to avoid the gastrointestinal drawbacks of sodium bicarbonate. Serial or chronic loading of Sb was found to be a very effective strategy in reducing gastrointestinal upset in many studies (McNaughton et al., 2000; Barber, 2010). This method is also more advantageous than the acute loading because this approach would eliminate the need for any

supplementation on race day and this kind of strategy would be welcomed by many athletes who would gladly avoid the distractions and possible adverse side effects especially on the match day (Burke & Pyne, 2007). For acute loadings, the best protocol determined for bicarbonate loading involves the dose 0.3 g/kg BM of pure NaHCO<sub>3</sub>, which should be taken 120–150 min before the start of exercise. The supplement should be co-ingested with a small high-carbohydrate meal to optimize blood alkalosis and reduce the occurrence of GI symptoms according to the study of Carr, Slater, Gore, Dawson and Burke (2011). Nonetheless it should be noted that there are still some people who are very sensitive as stated in the research of McNaughton et al. (2008) and it was also noted that approximately 10 percent of athletes do not tolerate sodium bicarbonate well. In this study, the questionnaire related with the severity of the feeling after ingestion helped the researcher to understand and monitor the degree of current GI distress of the players.

Analysis of the questionnaire was; at 60 minutes after ingestion, the severity of four of the nine symptoms was significantly ( $p < 0.05$ ) higher for the NaHCO<sub>3</sub> condition than for the placebo condition. Besides this, at 60 minutes after ingestion, the severity of three of the nine symptoms was significantly ( $p < 0.05$ ) higher for the 'NaHCO<sub>3</sub> 60' condition than the 'NaHCO<sub>3</sub> 0' condition. Another significant ( $p < 0.05$ ) difference was found within the placebo conditions, at between baseline and 60 minutes later ingestion, the severity of one of the nine symptoms was significantly ( $p < 0.05$ ) higher for the condition 'placebo 0' than 'placebo 60'.

These results are comparable to results of others who have also reported negative GI effects including gut fullness and abdominal discomfort (Cameron et al., 2010; Price et al., 2003) and sickness and stomach ache (Van Montfoort, 2004) after NaHCO<sub>3</sub> ingestion. Some participants

in this study experienced vomiting and diarrhoea either at baseline or after 60 minutes after the ingestion, but as expected the complaints were very light. Even though symptoms such as stomach bloating and gut fullness are likely to cause discomfort for athletes, vomiting and diarrhoea will have more serious consequences on physical performance (Cameron et al., 2010). On the current study, thanks to the serial loading method, vomiting and diarrhoea were not a problem for the  $\text{NaHCO}_3$  condition with the onset of exercise. It would be unrealistic to expect football players or any athlete to deal with these unwanted GI symptoms in a game-play situation. In addition to this, GI discomfort symptoms may also impede the physiologic preparation for a game. Researchers (Cameron et al., 2010) found that symptoms of flatulence and diarrhoea persisted into the 24 hrs after experimental testing of that study, which may possibly interfere with recovery and subsequent training sessions. Similar to the study of Cameron et al. (2010) the degree of GI discomfort observed in the current study was more pronounced than in other investigations (Price et al., 2003; Van Montfoort, 2004), which may be a result of the nature of the health priority performance test.

After reviewing the literature, the majority of the exercise performance test was performed on a cycle ergometer in a laboratory under controlled conditions, which is not completely representative of the body movements required in most team sports (Cameron et al., 2010). Running, an important part of team sport is likely to stress the GI tract more than a non-impact motionless performance test (Peters, DeVries, Vanberge-Henegouwen & Akkermans, 2001 as cited in Cameron et al., 2010). It was thought that it is necessary to investigate the tolerance of  $\text{NaHCO}_3$  using a sport-specific performance test that included ground running, to more directly replicate match play. It is believed that this would provide a more realistic view of actual GI tolerability.

In spite of the fact that the Loughborough Intermittent Sprint Test was designed to stimulate the activity patterns observed during a game of soccer, this test still had a few minor drawbacks such as lack of activities with a ball, running backwards and jumping (Nicholas, 2000). However, this test is still very reliable and gives researchers an opportunity to measure the performance and also metabolic responses to free-running activities, at the same time, maintaining sufficient control over the exercise regimen and environmental conditions (Nicholas, 2000). As Nicholas (2000) mentioned, the blood lactate levels are  $\sim 6 \text{ mmol}\cdot\text{l}^{-1}$  during the LIST, similar to this, Bangsbo (1994) suggests that blood lactate levels have been reported to rise to  $4.0\text{--}9.5 \text{ mmol}\cdot\text{l}^{-1}$  during the match. As football is a prolonged interval characterized activity in which there are periodic bouts of intense sprints, pre-match Sb ingestion may not be appropriate for football players. Maclaren (2003) concluded that "...it is unlikely that use of alkalinizers would be appropriate. This is due in particular to the prolonged nature of the game" (Maclaren as cited in Reilly & Williams, 2003a).

### *Limitations*

The findings of this study could have been affected by a number of factors. The small number of subjects used means that an anomalous result from just one individual will have quite a large effect on the validity and significance of the data (Gravetter & Wallnau, 2004); as performance on any given day can be affected by numerous different aspects it is to be expected that at least one individual will over or under perform in relation to their other test sessions.

Individual performance in each trial could have been affected by injury, illness, diet, training, social life related factors such as alcohol, race schedules, amount of sleep, and motivation. None of these were controlled in this study, although attempts were made to keep the trials as

consistent as possible by testing every trial at the same time, in the same place, and by keeping participants in the same pairs or groups each session. In addition to this, there are some possible limitations beyond these factors.

Measuring Performance: The Loughborough Intermittent Sprint Test was used for measuring sprint times, exhaustion times and rating perceived exertion. In this test, maximal effort may vary from each subject, which may underestimate peak sprint times and may cause confounding interpretation of results. All subjects, however, will be instructed to give maximal effort throughout the entire sprint trial and will be given verbal encouragement.

Adherence: Participants were expected to adhere to the dosing protocol through the consumption of each supplement or placebo during the loading days. Subjects were required to return the supplementation containers to the researcher for refilling. Researchers also communicated with subjects via phone, to confirm that they adhered to this protocol each loading day.

Gastrointestinal side effects: Sodium bicarbonate ingestion has been shown to produce gastrointestinal side effects during exercise (Cameron et al., 2010). Feelings of nausea, vomiting or stomach cramping can potentially hinder a subject's maximum effort and/or performance. However, to reduce these symptoms, subjects ingested each supplementation in four smaller doses at 9:00 a.m., 12:00 p.m., 6:00 p.m. and 10:00 p.m. throughout the ingestion period and fasted on test day.

Training effect: There is also the possibility of both a training effect and learning effect affecting the results, especially in studies that were looking for a small improvement. It

is possible that not only would the participants have improved due to their own training being completed on a day-to-day basis. But as the experiment was completed over a period of twelve days there was a small possibility that they could also have improved their performance due to the effects of the maximal exercise on their physiological make-up. Further, a learning effect may also have occurred as the participants became more familiar with what was expected of them and became used to the feelings of fatigue that they would experience. This, however, appears unlikely to be a key factor in this study comparison of the first LIST trial (control), used for familiarisation, to the experimental placebo and Sb trial. Because when looking at the average sprint times, there was no difference found between the average of all sprint times in control and placebo trials (2.78 s in both).

### *Improvements*

It is possible to alter the experimental protocol in various ways to potentially improve the results obtained. As the study was entirely performance based it could be that the use of biochemical markers such as blood pH, bicarbonate and lactate levels would provide greater insight into the time values obtained. To give an example, the changes within each period (during the eleven sprints) did not test for any significant differences between the first sprint and the eleventh.

Further control over participant behaviour is needed. Factors such as alcohol or any other stimulating substance consumption in the 24 hours prior to exercise testing should be monitored, or where possible, removed.

Monitoring of diet, perhaps in the form of food intake records on a daily basis will be helpful as the macronutrient content of the diet can potentially affect performance (Maughan & Greenhaff, 1991).

Recruiting a larger number of participants is necessary in order to increase the power (validity) of the results. The variation associated with a small experimental group strictly limits the trends and conclusions that can be drawn from the data collected.

In addition to the number of the participants, recruiting well-trained football players is recommended, however researchers should take into account the difficulties of recruiting and working with professional and semi-professional players because

The use of questionnaires needs to be considered more carefully as a more appropriate administration may result in the collection of critical information concerning the degree and timeframe of any GI symptoms experienced.

Finally, the study could also be conducted at a point in the season where players' training would be more consistent, for example at the end of the season, before the end of season break, or just prior to the beginning of the season.

## **Chapter - 6**

### **Conclusion**

In summary, it was found that, 1) Sodium bicarbonate loading produced significantly greater sprint performance than placebo between 36-69 minutes of the football specific exercise session (LIST); 2) Two days of Sb supplementation was found sufficient to increase repeated sprint performance compared to the placebo trial, besides not having any serious GI distress complaints; 3) Sb supplementation was not found to be effective in increasing the exhaustion time in an exercise session lasting for 90 minutes .

Considering that, this current study, as well as research conducted by Bishop & Claudius (2005), found similar benefits from using Sb as an ergogenic aid. This previously mentioned study also conducted a prolonged (72 min) test, in which the results of this research gave a positive rationale to continue to research the use of Sb in prolonged exercise sessions for current study. More must be concluded before researchers can endorse using a supplementation of sodium bicarbonate with confidence for performance enhancement.

Reilly and Williams (2003b) highlight the importance of physical performance in a football game, “when teams roughly equal in skill and tactical knowledge meet, the one with the higher overall fitness level will have the advantage of being more able to cope with a fast pace of play”. Coaches, trainers and sports scientists acknowledge that preparation for competitive match-play calls for a systematic approach. Consideration of individual fitness profiles and the contribution these make to the team must be an integral part of this systematic approach (Reilly, 2007).



### *Practical Applications*

Our data suggests that a two-day supplementation of sodium bicarbonate may increase sprint times due to increased buffering power in the blood. Sprint times during the middle of the game (3<sup>rd</sup> and 4<sup>th</sup> periods) were approximately 3.2% greater at Sb condition compared to the placebo and it is expected that with longer sprint distances, players may achieve better improvements. This may seem minimal, but at the elite level, this can have a profound effect on improving high intensity sprint performance. Furthermore, this study also contributed to a few studies, which found significant improvement in performance via supplementation of sodium bicarbonate in split doses over two days (serial loading) and at the same time without having any serious GI distress. Although the changes in fatigue ratings did not differ in this study, there are some studies, which found lower fatigue ratings in Sb groups when compared to placebos. If further studies can find improvement in RPE in a football specific exercise, this may give an athlete a competitive advantage over non-supplemented athletes. Related to small changes in sprint times, these tiny improvements are particularly important for those involved in sprint events where making finals and winning medals can be determined by hundredths of a second. For football, obviously it is not the same thing due to the nature of intermittent prolonged exercise but enhancing the sprint performance of a player could change the course of the game unexpectedly and enhancing the sprint performance of the whole team will definitely improve their competitive power and this can make sodium bicarbonate a meaningful ergogenic aid. Furthermore, when considering that there were no significant gastrointestinal side effects found from each of these conditions, this suggests that the power output benefits gained from sodium bicarbonate are worthwhile.

## **Chapter - 7**

### **Future Research**

The data collected over the course of this study seem to suggest the need for further research into the effects of alkalosis on the prolonged intermittent exercise performance of athletes on a greater sample size. Especially, more work on the transfer of bicarbonate loading from the laboratory or routine training to the actual competitive environment is needed. Furthermore, the effects of a smaller dosage, perhaps a 0.3 or 0.4g/kg body weight serial loading method could also be explored for such exercise patterns similar to this study. Apart from these:

Future work may be required to investigate the effects of serial NaHCO<sub>3</sub> supplementation on elite/professional (highly trained) football players. Recruiting elite athletes is important to understand the effects of Sb on professionals because less capable subjects may potentially be more capable of utilising the improved buffering capacity theorised to be available after NaHCO<sub>3</sub> ingestion (Maughan & Greenhaff, 1991). It is still questionable if the level of performance will change the result of Sb supplementation compared to less trained subjects.

The influence of multiple loading of ergogenic aids on the possible gastrointestinal distress is also unknown. Burke and Pyne (2007, p. 96) stated that “anecdotal reports in competitive sport indicate that there are athletes who use several ergogenic aids in combination without supervision and pay little or no attention to the possibility of interactive effects”. Further research is needed to identify the combined effect of several ergogenic aids because there is an abundance of research on the effects of sodium bicarbonate. More research needs to be

conducted to determine the physiological mechanism effects of ergogenic aids used in combination.

Specifically for the serial loading method, the optimal dose-response and timing interaction over the days leading to competition should be explored.

According to many studies it is stated that sodium bicarbonate can (significantly) lower the muscle  $[H^+]$  not only during the exercise but also in the rest period. This may help to speed up the recovery process for football players who have a limited time to recover before the next match. In the study of Verbitsky et al. (1997) it was found that the Sb group had higher torque than the placebo group even after the post-fatigue measurements, indicative that the buffer capacity in the blood was improved in the recovery process as well ( $p > 0.05$ ) (reducing muscle fatigue and enhancing recovery.) Therefore, a future study investigating these effects of Sb is encouraged and if it is found to be a significant improvement, it will be useful for recovery of the whole football team players between matches/training.

The study could be repeated using another football specific test, including ball activities, which would replicate real matches, but would also be difficult to control due to environmental interference.

Practical strategies to limit gastrointestinal stress need to investigate the issues of timing, split doses, and powder versus capsule loading and would be helpful for athletes and coaches. The issue of long-term adaptation to chronic bicarbonate supplementation also needs investigation.

Finally, further research is certainly necessary, with many trends and interactions still to be identified and clarified. Resolution of some of these issues should lead to enhanced administration of bicarbonate use as an ergogenic aid in training and competition across a range of sports.

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## APPENDIX A.



# Participant information sheet

## **The Effects of 2 Days Sodium Bicarbonate Loading on Simulated Football Performance.**

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

### **What is the purpose of the study?**

This research is being undertaken on healthy adults. The project is to find out how, if at all the, which tests effects of sodium bicarbonate loading in football game.

### **Why have I been chosen?**

You have been chosen because you are a football player.

### **Do I have to take part?**

It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

### **What will happen to me if I take part?**

You will need to join 4 sessions of exercise tests and need to take test beverages as according to researcher's directions. About exercise tests; first one is Bleep test which is participants need to run between 20 meters distance and this test will predict the participants' maximal oxygen uptake. Other sessions are all LIST test which is participants will be asked to walk/jog/run/sprint and rest during 90 min duration.

**What are the possible disadvantages and risks of taking part?**

There are no disadvantages or serious risks foreseen in taking part in the study. In some studies there had been shown some side effects of bicarbonate loading originated from high dose loading in a single dose but the studies conducted on multiple doses in consecutive days found no serious side effects.

**What are the possible benefits of taking part?**

By taking part, you will be contributing a research which tests effects of sodium bicarbonate loading in football game. Also participants will learn how really fit they are during the tests and have an experience how scientific studies are conducting in sports science.

**What if something goes wrong?**

If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Applied Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 00 44 1244 513055.

**Will my taking part in the study be kept confidential?**

All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

**What will happen to the results of the research study?**

The results will be written up into a dissertation for my final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

**Who is organising the research?**

The research is conducted as part of a MSc in Exercise & Nutrition Science within the Department of Clinical Sciences at the University of Chester. The study is organised with supervision from the department, by Orcun Kurum, an MSc student.

**Who may I contact for further information?**

If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

*Orcun Kurum. @chester.ac.uk.*

**Thank you for your interest in this research.**

## (2. Version of PIS Form-Turkish Version)

### Katılımcı Bilgilendirme Formu

#### **2 günlük sodyum bikarbonat yüklemesinin temsili futbol performansına etkisi.**

Araştırma çalışmasına katılımcı olmanız için davet edilmiş bulunmaktasınız. Karar vermeden önce araştırmanın neden yapıldığını ve ne içerdiğini anlamanız önemlidir. Aşağıdaki bilgileri lütfen okuyunuz ve gerekirse bu konuyu başkaları ile de tartışınız. Eğer anladığınız bir şey var ise veya daha fazla bilgi almak istiyorsanız bize sorabilirsiniz.

Paragrafı okuduğunuz için teşekkürler.

#### **Çalışmanın amacı nedir?**

Çalışma sağlıklı bireyler üzerinde yapılacaktır. Sodyum bikarbonat besin desteğinin futbol performansına etkisi olup olmadığı araştırılmaktadır.

#### **Niye ben seçildim?**

Futbolcu olduğunuz için seçilmiş bulunmaktasınız.

#### **Katılmalı mıyım?**

Katılıp, katılmayacağınız size bağlıdır. Eğer katılma kararı alırsanız size izin formu verilecek ve kabul ettiğinize dair imzalamanız istenecek ve böylece sizden onay alınacaktır. Eğer herhangi bir sepeten ötürü çalışmadan ayrılmak isterseniz bunda özgürsünüz.

#### **Katılırsam ne yapmam gerekiyor?**

4 tane egzersiz seansına katılmanız gerekmektedir ve araştırmacının belirttiği şekilde test sıvılarından içmeniz gerekmektedir. Egzersiz testleri hakkında, ilk test Bleep test olarak adlandırılan yarım saatten az süren bir aerobik testtir. Bu test ile katılımcının maksimum oksijen kapasitesini ölçülecek ve onun seviyesine uygun LIST testi uygulanacaktır. Sonraki 3 test de LIST testi olup için yürüme/hafif koşu/hızlı koşu/sprint ve dinlenmenin de olduğu 90 dakikalık bir testtir.

#### **Araştırmaya katılmanın dezavantajı veya riskleri nelerdir?**

Araştırmaya katılmanızın dezavantajı veya ciddi riskleri bulunmamaktadır. Her ne kadar yapılan bazı çalışmalarda bazı hafif yan etkiler gözlemlense de bunun sebebi o çalışmalarda uygulanan tek doz protokoludur. Bölünmüş dozlar ile birden fazla güne yayılarak uygulanan çalışmalarda herhangi bir yan etkiye rastlanmamıştır.

**Araştırmaya katılmamanın ne gibi artısı olacaktır?**

Bu çalışmada katılımcı olarak sodyum bikarbonat besin desteğinin futbolda etksi olup olmadığının bulunmasına katkıda bulunacaksınız. Bunun yanında yapılan testler sayesinde gerçek fitness seviyeninizi öğrenecekseniz ve spor bilimlerinde bilimsel çalışmaların nasıl yapıldığına dair tecrübe edinmiş olacaksınız.

**Yolunda gitmeyen birşey olursa?**

Eğer araştırma süresince şikayet etmek istediğiniz veya size yaklaşım biçiminde endişe duyduğunuz bir şey varsa veya maruz bırakıldıysanız lütfen Profesör Sarah Andrew, Dean of the Faculty of Applied Sciences, University of Chester Parkgate Road, Chester, CH1 4BJ, 01244 513055 adresine bildiriniz.

**Katımcı olacağım gizli kalacak mı?**

Araştırma süresince sizden alınan tüm bilgiler sadece araştırmacı tarafından bilinecek ve tamamen gizli kalacaktır

**Araştırma sonuçları ne yapılacaktır?**

Araştırmadan elde edilen sonuçlar Master eğitimim için yapacağım tez araştırmasında kullanılacaktır. Katılımcılar, ileride oluşturulacak rapor veya yayımlanma durumunda tanımlanmayacaklardır.

**Araştırmayı kim organize etmiştir?**

Araştırma Chester Üniversitesi, Egzersiz ve Beslenme Bilimi Master programı, Klinik Bilimler Departmanının bir bölümü olarak düzenlenmiştir. Çalışma Master öğrencisi Orçun Kürüm tarafından organize edilmiştir.

**Daha fazla bilgi nereden alabilirim?**

Katılıp katılmayacağınıza karar vermeden önce araştırma ile ilgili daha fazla bilgi istiyorsanız, aşağıdaki mail adresinden bize ulaşabilirsiniz:

*Orcun Kurum. @chester.ac.uk.*

**Çalışmam ile ilgilendiğiniz için teşekkürler.**

## APPENDIX B.

# Consent Form



**Title of Project:** The Effects of 2 Days Sodium Bicarbonate Loading on Simulated Football Performance.

**Name of Researcher:** Orcun Kurum

Please Tick Box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected.
3. I agree to take part in the above study.

☐☐☐

\_\_\_\_\_  
Name of Participant

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Researcher

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

1 copy for participant; 1 copy for researcher



(2. Version of Consent Form-Turkish Version)

## İzin Belgesi



**Projenin başlığı:** 2 günlük sodyum bikarbonat yüklemesinin temsili futbol performansına etkisi.

**Araştırmacının adı:** Orçun Kürüm

Lütfen Kutuya Tik Atınız

2. Yukarıda bahsi geçen çalışma ile ilgili bilgi formunu okuduğumu ve anladığımı ayrı soru sorma şansı verildiğini onaylıyorum. ☐
3. Gönüllü olarak katılıyorum ve arzu ettiğim takdirde, hiçbir bahane sunmaksızın çalışmadan çekilebileceğimi biliyorum. ☐
3. Bahsedilen çalışmada yer almayı kabul ediyorum. ☐

\_\_\_\_\_  
Katılımcının Adı

\_\_\_\_\_  
Tarih

\_\_\_\_\_  
İmza

\_\_\_\_\_  
Araştırmacı

\_\_\_\_\_  
Tarih

\_\_\_\_\_  
İmza

1 kopya katılımcı için; 1 kopya araştırmacı için

## APPENDIX C.

### Permission Paper for University Football Players

<p><b>Doğu Akdeniz Üniversitesi</b> <b>Eastern Mediterranean University</b> <small>Spor İşleri Müdürlüğü / Sports Office</small></p>	<p><i>"Uluslararası Kariyer İçin"</i> <i>"For Your International Career"</i></p> 
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**PERMISSION PAPER FOR UNIVERSITY SPORTSMEN**

To whom it may concern,

Mr. Kurum requested permission for participate our football players in his research thesis. As I am the Head of Sport Office in EMU, I admit to give full permission to Mr. Kurum for participate our players in the football team as long as they accept to be a volunteer.

Regards,

Date: 15-04-2011



**Cemal KONNOLU**  
Director of Sports Office  
EASTERN MEDITERRANEAN UNIVERSITY

<p><small>Gazimağusa, North Cyprus, via Mersin 10 TURKEY</small></p>	<p><small><a href="http://sporemu.edu.tr">http://sporemu.edu.tr</a> <a href="mailto:spor@emu.edu.tr">spor@emu.edu.tr</a> <a href="http://www.emu.edu.tr">www.emu.edu.tr</a></small></p>	<p><small>Tel: +90 392 630 2308 - 630 1341 - Fax: +90 392 630 2319</small></p>
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### Permission Paper for University Facilities



### PERMISSION PAPER FOR UNIVERSITY FACILITES

To whom it may concern,

Mr. Kurum requested permission for using our facilities in the University within his dissertation. As I am the Head of Sport Office in EMU, I admit to give permission to Mr. Kurum for using the university's facilities (Sports Hall, Heart Rate Monitor ect.) I will also supply a technician to guide Mr. Kurum when he is conducting his test.

Regards,

Date: 15-09-2011



Cemal KONNOLU  
Director of Sports Office  
EASTERN MEDITERRANEAN UNIVERSITY

**APPENDIX D.**

**Assessment of Gastrointestinal Symptoms**

**Subject name or code:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Time:** \_\_\_\_\_

**Gastrointestinal Symptoms**

This questionnaire asks you to include any gastrointestinal (gut) symptoms you may have experienced from just after ingestion and 60 min. after ingestion.

1.

Did you experience any unusual gastrointestinal (gut) symptoms?

YESNO
2.

If you answered yes to Question 1, please identify which symptom/s you experienced by ticking the appropriate box/es below and rate your severity of symptoms by placing a vertical mark on the line.

	no symptom	severe symptom
<input type="checkbox"/> nausea	_____	_____
<input type="checkbox"/> flatulence	_____	_____
<input type="checkbox"/> stomach cramping	_____	_____
<input type="checkbox"/> belching	_____	_____
<input type="checkbox"/> stomach-ache	_____	_____
<input type="checkbox"/> bowel urgency	_____	_____
<input type="checkbox"/> diarrhea	_____	_____
<input type="checkbox"/> vomiting	_____	_____
<input type="checkbox"/> stomach bloating	_____	_____

source: Cameron, McLay-Cooke, Brown, Gray, & Fairbairn, 2010.

(2. Version of GI Symptoms-TurkishVersion)

## Gastrointestinal (mide/bağırsak ile ilgili) Belirtilerin Değerlendirilmesi

Bireyin adı veya kodu: \_\_\_\_\_

Tarih: \_\_\_\_\_

Saat: \_\_\_\_\_

### Gastrointestinal Belirtiler

Bu anket karşılaşılabileceğiniz bütün gastrointestinal belirtileri kapsayacak şekilde hazırlanmış olup test sıvılarının tüketiminden hemen sonra ve 60 dk. sonra doldurulması gerekmektedir.

3. Herhangi bir olağan olmayan gastrointestinal belirti ile karşılaştınız mı?

EVET HAYIR

4. Eğer cevabınız EVET ise, lütfen aşağıdaki kutuya/lara tik işareti koyarak hangi belirti/ler ile karşılaştığınızı tanımlayınız ve her bir belirtinin yanındaki şerite dikey bir çizik koyarak belirtinizin şiddetini değerlendirin.

	belirti yok	şiddetli belirti
<input type="checkbox"/> mide bulantısı	_____	_____
<input type="checkbox"/> bağırsakta şişkinlik	_____	_____
<input type="checkbox"/> mide krampı	_____	_____
<input type="checkbox"/> geğirme	_____	_____
<input type="checkbox"/> mide ağrısı	_____	_____
<input type="checkbox"/> bağırsak telaşı	_____	_____
<input type="checkbox"/> ishal	_____	_____
<input type="checkbox"/> kusma	_____	_____
<input type="checkbox"/> midede şişkinlik	_____	_____

source: Cameron, McLay-Cooke, Brown, Gray, & Fairbairn, 2010.

**APPENDIX E.**

**Risk Assessment Form**

Name.....

Potential Hazard	Control Measures to be Adopted
Trips and falls during the test	First aid facilities available in sports hall and trained persons in attendance.
Pre-existing health problems	Health pre-screening questionnaire to exclude (Appendix-12)

Signature and date

.....

**APPENDIX F.**

**Borg RPE Scale**

**RPE 6-20 Scale**

Borg, G.A.V. 1998. *Borg's Rating of Perceived Exertion and Pain Scales*.  
Champaign, IL: Human Kinetics.

(2. Version of Borg RPE Scale-Turkish Version)

## Borg RPE (Hissedilen Efor Derecesi) Skalası

### Hissedilen Efor Derecesi (RPE)

Borg, G.A.V. 1998. *Borg's Rating of Perceived Exertion and Pain Scales*.  
Champaign, IL: Human Kinetics.



**APPENDIX G.**

**Data Collection Sheet for LIST**

Code of the participant: \_\_\_\_\_ LIST level: \_\_\_\_\_  
Date: \_\_\_\_\_ Weight : \_\_\_\_\_  
Time: \_\_\_\_\_ Dose : \_\_\_\_\_

Part	Period		Time	Heart Rate	RPE
Part A	Period 1	Walk			
		Sprint	<div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div>		
		jog			
		Cruise			
		<i>rest</i>			
	Period 2	Walk			
		Sprint	<div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div>		
		Jog			
		Cruise			
		<i>rest</i>			
	Period 3	Walk			
		Sprint	<div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div>		
		Jog			
		Cruise			
		<i>rest</i>			
	Period 4	Walk			
		Sprint	<div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div>		
		Jog			
		Cruise			
		<i>rest</i>			
	Period 5	Walk			
		Sprint	<div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div> <div></div>		
		Jog			
		Cruise			
		<i>rest</i>			
Part B	Final Period	Time to fatigue			

## APPENDIX H.



### Pre-test Questionnaire

#### **The Effects of 2 Days Sodium Bicarbonate Loading on Simulated Football Performance.**

**Researcher :** *Orcun Kurum*

Name: \_\_\_\_\_ Test date: \_\_\_\_\_

Contact number: \_\_\_\_\_ Date of birth: \_\_\_\_\_

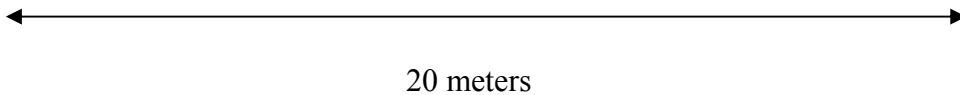
In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. Has your doctor ever said that you have a heart condition *and* that you should only perform physical activity recommended by a doctor? YES/NO
2. Do you feel pain in the chest when you perform physical activity? YES/NO
3. In the past month, have you had chest pain when you were not performing physical activity? YES/NO
4. Do you lose your balance because of dizziness *or* do you ever lose consciousness? YES/NO
5. Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity? YES/NO
6. Is your doctor currently prescribing drugs for your blood pressure or heart condition? YES/NO
7. Are you pregnant, or have you been pregnant in the last six months? YES/NO
8. Have you injured your hip, knee or ankle joint in the last six months? YES/NO
9. Do you know of any other reason why you should not participate in physical activity? YES/NO

Thank you for taking your time to fill in this form. If you have answered 'yes' to any of the above questions, unfortunately you will not be able to participate in this study.

## **APPENDIX I.**

# **Progressive Shuttle Run Test (Bleep Test)**



This test consist of shuttle running between two markers placed 20m apart at increasing fast speeds. Test will take place in a sports hall and a computer will be used to play the appropriate audio for conducting the test. The running speed will increase 0.14 m /s (0.5 km/hr) each minute, this change in running speed can also be described as a change in level. Finally, the subject will run in groups of no more than four to stimulate competition and ensure a maximal effort (Ramsbottom, Brewer, & William, 1998).

## APPENDIX J.



University of  
Chester

*Faculty of Applied Sciences  
Research Ethics Committee*

Tel 01244 511740  
Fax 01244 511302  
frec@chester.ac.uk

Orcun Kurum

8<sup>th</sup> July 2011

Dear Orcun,

**Study title:** The Effects of 2 Days Sodium Bicarbonate Loading on Simulated Football Performance.  
**FREC reference:** 544/11/OK/CS  
**Version number:** 1

Thank you for sending your application to the Faculty of Applied Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	May 2011
Appendix 1 – List of References	1	April 2011
Appendix 2 – C.V. for Lead Researcher	1	April 2011
Appendix 3 – Participant Information Sheet	1	April 2011
Appendix 4 – Participant Consent Form	1	April 2011

Appendix 5 – Written Permission – Eastern Mediterranean University	1	April 2011
Appendix 6 – Questionnaire	1	April 2011
Appendix 7 – Risk Assessment Form	1	April 2011
Appendix 8 – Test Protocol - LIST	1	April 2011
Appendix 9 – Supplementation Protocol	1	April 2011
Appendix 10 - Borg RPE Scale	1	April 2011
Appendix 11 – Participant Screening Sheet	1	April 2011
Appendix 12 - Health Screen	1	April 2011
Appendix 13 – Bleep Test	1	April 2011
Response to FREC request for further information and clarification	1	June 2011
Response to FREC request for further clarification and information	2	June 2011

With the Committee's best wishes for the success of this project.

Yours sincerely,

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**Simon Alford**

Chair, Faculty Research Ethics Committee

**Enclosures Standard conditions of approval.**

C.c. Supervisor  
FREC Representative